FEEDS AND FEEDING

HENRY AND MORRISON

LIVE STOCK FARMING PROMOTES PERMANENT AND PROGRESSIVE AGRICULTURE

FEEDS AND FEEDING

A HANDBOOK FOR THE STUDENT AND STOCKMAN

EARLY EDITIONS BY

W. A. HENRY

EMERITUS PROFESSOR OF AGRICULTURE,
AND FORMERLY DEAN OF COLLEGE OF AGRICULTURE
AND DIRECTOR OF THE AGRICULTURAL EXPERIMENT STATION,
UNIVERSITY OF WISCONSIN

REWRITTEN BY

F. B. MORRISON

PROFESSOR OF ANIMAL HUSBANDRY
CORNELL UNIVERSITY

"The eye of the master fattens his cattle."

NINETEENTH EDITION, Unabridged

ITHACA, NEW YORK
THE HENRY-MORRISON COMPANY
1928

COPYRIGHT, 1923
BY
THE HENRY-MORRISON COMPANY

First edition published 1898; second edition 1900; third edition 1901; fourth edition 1902; fifth edition 1903; sixth edition 1904; seventh edition 1906; eighth edition 1907; ninth edition 1908. Tenth edition, rewritten and reset, published 1910; eleventh edition 1911; twelfth edition 1912; thirteenth edition 1913; fourteenth edition 1915. Fifteenth edition, rewritten and reset, published 1915; sixteenth edition 1916; seventeenth edition, August 1918; reprinted December, 1918, February, 1919, June, 1919, October, 1919, January, 1920, August, 1920, September, 1921, December, 1921. Eighteenth edition, rewritten and reset, published September, 1922. Illustrated edition published February, 1923; reprinted November, 1923; January, 1927; September, 1928.

Translated into Portugese by F. M. Draenert, Sao Paulo, Brazil, 1907.

Translated into Russian under direction of Paul Dubrovsky, editor of "Agriculture and Forestry," and published by the Department of Agriculture, for the use of agricultural schools and other institutions of the Department, Petrograd, 1912.

Printed in the United States of America.

HAMMOND PRESS
W. B. CONKEY COMPANY
CHICAGO

PREFACE

Feeds and Feeding, first published in March, 1898, was received with immediate and widespread favor by practical stockmen, as well as by the professors and students of animal husbandry in our agricultural colleges and secondary schools. The plan of the book had been laid along original lines, and neither labor nor expense was spared in its preparation. In 1910, after nine editions had come from the press, the book was entirely rewritten and improved in many ways. Again in 1915 the book was completely rewritten and enlarged to include the recent information, both scientific and practical. To this revision Professor Morrison, who had assisted thruout the first revision and who now became joint author, devoted much time, with a corps of trained assistants, during a period of over two years. The favor with which this second revision was received exhausted two large editions in less than two years and nine printings of the last edition have been required in rapid succession.

During the past few years exceedingly important discoveries have been made concerning the science and practice of live stock feeding. Furthermore, economic conditions have radically changed. Therefore, Professor Morrison has again entirely rewritten the book to include the latest information and to adapt it to the changed economic conditions since the World War. Just as in the previous revision, the results of many important investigations, completed so recently as not yet to be in print, have been furnished by scientists thruout the country, in order that the findings might be presented in this revision.

It is the aim to give in *Feeds and Feeding* an unbiased and condensed presentation of the most important findings of the investigators of both the Old and New Worlds in the science of animal nutrition, together with the most important results of the vast number of feeding trials which have been conducted at the experiment stations in the United States and other countries, the whole being rounded out by the practical experiences of many of the leading stockmen of America. The authors have not relied merely on a thoro study of the published information on nutrition and stock feeding, but have gained personal contact with conditions in various districts by extensive travel.

Part I presents briefly the fundamental principles of animal nutrition, including the most recent discoveries of the scientists. The bearing of these principles upon the practical feeding of live stock is given especial emphasis. Particular attention is given to the newer discoveries in nutrition, including the functions and importance of vitamines and mineral matter, as well as the differences in the quality of food proteins from various sources.

Chapter		Page
XXXII.	General Care of Sheep and Lambs—Fattening—Hot-house Lambs—Goats	577
XXXIII.	General Problems in Swine Husbandry	599
XXXIV.	Feeds for Swine	623
XXXV.	Feed and Care of Swine	684

Appendix

Table I.	Composition of American Feeding Stuffs	709
Table II.	Digestibility of Feeding Stuffs	722
Table III.	Digestible Nutrients and Fertilizing Constituents of Feeding Stuffs	728
Table IV.	The Wolff-Lehmann Feeding Standards	744
Table V.	The Morrison Feeding Standards	746
Table VI.	Net Energy Values of Feeding Stuffs for Ruminants	749
Table VII.	The Mineral Constituents of Feeding Stuffs	752
Table VIII.	The Weight of Various Concentrates per Quart	753
Table IX.	The Vitamine Content of Feeding Stuffs	754
Index		756

INFORMATION TO THE READER

When seeking information on any subject presented in this book, the reader should first consult the copious index, the figures of which refer to the *page* on which the topic is presented. Additional information bearing on the subject given at other places may be found by following up the numerous references set in black-face figures in parentheses, occurring in the body of the text. These figures refer to the numbered *black-face* sideheads, and *not to the pages.*

LIVE STOCK UTILIZE FEED OTHERWISE WASTED

In stock farming the entire corn crop—stover as well as grain—is utilized. On the other hand, in grain farming the stover is wasted.

RAKING UP CORN STALKS AND BURNING THEM

On grain farms the corn stalks are commonly allowed to waste away in the fields. Sometimes they are even raked up and burned, which causes a heavy loss of fertility.

MUCH FERTILITY IS LOST WHEN HAY IS SOLD FROM THE FARM

Few farmers realize that each ton of hay or grain hauled from the farm removes at least $6 to $10 worth of fertility. (From U. S. Department of Agriculture.)

MARKETING CROPS THRU FATTENING CATTLE

When crops are fed to stock and proper care is taken of the manure, but little fertility is lost. Also the expense of marketing is much less than when hay or grain must be loaded and hauled to market. (From U. S. Department of Agriculture.)

INTRODUCTION

LIVE STOCK AND PROFITABLE FARMING

Farmers, as well as most other classes of people in the United States, have passed thru difficult and perplexing times during the days of readjustment since the close of the World War. These years have brought lessened profits and even serious losses to many. At such a time it is especially important that all possible means be taken to lower the cost of producing farm products thru adopting the most efficient methods and practices, else no profit will remain for the farmer.

Fortunately, in no line of agriculture is there a greater opportunity to do this than in live stock production. This is because recent epoch-making discoveries have made possible much greater efficiency in the feeding of our live stock. Furthermore, far-sighted stockmen have been improving the various breeds of animals until today our dairy cattle, beef cattle, sheep, and swine are remarkably efficient animals for converting the crops of the fields into food for man and products useful to him. Only when a farmer plans his feeding operations with a thoro understanding of the food requirements of these highly developed animal machines can he hope to secure from them the most profitable production.

Many of the discoveries in animal nutrition and stock feeding are so recent that the results have not as yet been presented in publications which reach the majority of practical farmers. Consequently, they are not acquainted with these developments of the past few years, or else do not understand their true relation to farm practice. In the preparation of this edition especial attention has been given, therefore, to the recent developments in our knowledge concerning the science and practice of stock feeding. Thruout the book the primary object has been to point out clearly ways in which farm animals may be fed more efficiently and economically so that they will return more profit to their owner.

1. Functions and importance of live stock.—The animals of the farm should be regarded as living factories that are continuously converting their feed into products useful to man. A fact of great economic importance is that a large part of the food they consume is of such character that humans can not directly utilize it themselves. Among the products yielded by the farm animals are not only articles of human diet, such as meat, milk, and eggs, but also such materials as wool, mohair, and hides, which are needed for clothing and other purposes. Another product of greater aggregate money value than any one of these is the work performed by horses and other draft animals. The great importance of animal husbandry in the United States is shown by the fact that the

total value of all the horses, mules, cattle, sheep, and swine on January 1, 1922, was estimated to be about $4,780,000,000.

As the population of our country becomes more dense, most naturally and properly a smaller portion of the crops raised will be fed to animals and a larger part consumed directly by humans. This change must come with the increased demand for human food, since even high-producing animals are able to convert only a part of the feed they eat into food for our consumption. However, the actual condition is surprising. While our population has increased 39 per cent during the 20-year period, 1900 to 1920, the number of beef cattle and sheep has actually decreased during the past 20 years, and the number of swine has increased but 15 per cent. Dairy cows alone kept pace with the increase in population. These data show clearly that if meat is to continue to hold its place in our diet, first of all consumers must fully understand the importance of meat as a food and be willing to pay a price fair to the producer. Also, American farmers must more thoroly appreciate the advantages of stock farming and better understand the principles and methods which are essential to its success.

2. Live-stock farming and soil fertility.—Lured by the high prices which ruled for grain and other crops during the World War, many farmers all over the country have sold their crops for cash, rather than following the wiser plan of marketing a portion thru the feeding of live stock, and thereby maintaining a balanced agriculture. Seldom have they realized that with every ton of grain thus sold they are removing from their farms $8 to $10 worth of fertility. The loss thru such mining of the soil is gradual, but in a comparatively few years there will result none the less surely worn-out fields, lacking in plant food and humus, which must ever afterwards be fed with fertilizers to secure fair crops. However, if a part of the crops is fed to live stock and proper care taken of the resulting manure, most of the fertility may be retained on the farm, and the need of commercial fertilizers long delayed. Under intensive stock farming, where more or less milling by-products rich in fertilizing constituents are usually purchased and fed on the farm, the land will even become richer and more productive year by year, with but little need for commercial fertilizers.

3. Utilization of waste feed and land unsuited for tillage.—In exclusive grain farming the large amount of roughage, such as straw and corn stover, which results as a by-product in the growing of the cash crops, is not utilized in most instances. Such materials are merely in the way and are disposed of in the easiest manner, often by burning, without regard for the loss of vegetable matter, so much needed by the soil. In a well-planned system of stock husbandry all these materials are utilized for feed or bedding. Much forage which can not be consumed by humans and would otherwise be wasted is thus refined thru the agency of animals and converted into a form suitable for the nourishment of man, while

considerable of the organic matter is returned to the fields in the resulting manure. Immense amounts of by-products result from the manufacture of the cereals and other seeds into flour, breakfast foods, oils, etc. Altho not suited for humans, some of these by-products are among our most valued feeds for stock. As the density of population increases and the prices of foodstuffs advance, the feed supplied our farm animals must to an ever increasing extent consist of substances resulting secondarily from the making of human food, whether they be coarse roughages or milling by-products.

In some sections much of the land is so rough or stony that it can not be tilled economically. Here cattle will gather the grass on the smoother stretches and sheep will search out the herbage on the more inaccessible, rocky slopes. Over great areas of the West there is too little rainfall to warrant even dry farming, and irrigation will never be possible, either because of lack of water or the roughness of the land. Yet stock will thrive on the scanty but highly nutritious grasses and other forage. Thru well-planned systems of grazing, with additional feed in time of winter storm or parching drought, the western ranges should, at no far distant date, carry even more stock than they did before large areas were broken up into farms. In the cut-over districts of our country large areas of land may be profitably grazed by live stock before they are finally brought under tillage.

4. Distribution of labor.—Under exclusive grain farming the chief demand for labor is confined to the periods of preparing the land, planting the crops, harvesting, and later marketing the products. During the rush seasons labor is high-priced, and often hard to secure at any cost. On the other hand, live-stock farming offers employment thruout the entire year. Winter, when little other farm work can be done, is the very season when farm animals require the most care and attention, for they are then usually housed instead of at pasture. Because the live-stock farmer can thus offer steady employment he is usually able to secure men who are both more efficient and more reliable than he could otherwise obtain.

5. Intelligent and progressive agriculture.—The whole world over, the most enlightened and progressive agricultural districts are found where live stock provides one of the chief sources of income. This is due to several reasons: The live-stock farmer can not live from hand to mouth, but must providently lay in a store of feed for his animals thruout the winter months. This same care and foresight are then carried into his other activities. Under some systems of agriculture the returns from the year's crops all come in at once, which makes for extravagance and idleness, with resultant poverty until another crop is harvested. On the other hand, under most systems of live-stock farming, income is secured several times during the year.

The care and control of domestic animals, which are intelligent yet submissive to his will, tend to develop the best instincts in man and make

him kindly, self-reliant, and trustworthy. The good stockman grows proud of his sleek, well-bred animals and derives a satisfaction therefrom not measured in money. With pride he may hand down to his sons his reputation as a breeder. He is also able to leave them fertile fields which he has built up rather than robbed, a heritage bequeathed by but few grain farmers.

6. Profitable live-stock farming.— In the early days, with land low in price, pasturage abundant, and feed and labor cheap, making a profit from live-stock farming was comparatively easy, even tho one possessed little knowledge of the principles governing the feeding and care of stock. Conditions have now changed. The great western prairies no longer offer rich fields free for the taking, and hence thruout the country fertile land is now relatively high in price. While labor and feeding stuffs are much lower than under war-time conditions during the past few years, they are considerably higher than in early days. Therefore present times call for a more intelligent type of stock farming than has ruled in the past. Efficiency is especially necessary in making the difficult adjustments from the inflated war-time basis of costs and prices. In the long run, good profits will be realized in the future as in the past from stock farming, when the operations are planned with good judgment and with a thoro appreciation of the requirements of the various classes of animals. However, haphazard and unscientific animal husbandry should not and can not return a profit under present day conditions.

In the pioneer days of our country the feeds commonly used for live stock were restricted to the grains and forages grown on the farm. Knowledge of the value of these farm-grown products is not now sufficient for intelligent feeding. The problem is complicated by the host of by-products resulting from the manufacture of articles of human food which are offered on the markets as feeding-stuffs for stock. Many of these are valuable and economical supplements to the feeds raised on the farm. However, such products vary considerably in price and even more markedly in nutritive value. Most economical feeding is therefore possible only when the relative value of these different products compared with each other and with the farm-grown crops is clearly understood.

In seeking a knowledge of feeds and of feeding we must first consider the plant substances which provide the nourishment for farm animals and study the manner in which these compounds are built up in the living plant. Next we should learn how the food consumed by animals is digested and utilized within the body for the production of meat, milk, work, or wool, and should also study the requirements of each class of animals for food, water, shelter, and exercise. Only then are we in some measure in a position to understand the value and merits for each of the farm animals of the many different feeds, and finally to consider the principles of care and management, the constant observance of which is essential to the highest success in animal husbandry.

FEEDS AND FEEDING

Part I

PLANT GROWTH AND ANIMAL NUTRITION

CHAPTER I

THE PLANT; HOW IT GROWS AND ELABORATES FOOD FOR ANIMALS

I. Plant Growth

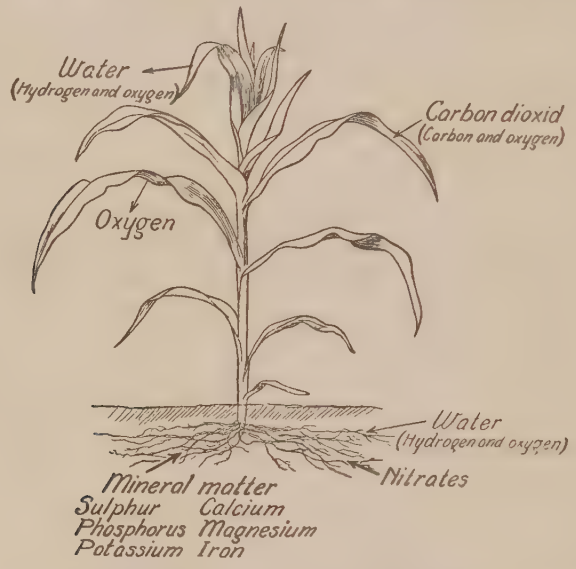
All food for animals, with the exception of air, water, and salt, is supplied either directly or indirectly by plants. To understand the feeding of live stock, one should therefore know how plants grow and build this food and of what it consists.

7. The food of plants.—Both plants and animals are composed of a great many substances or compounds—yet all are made up of a relatively small number of chemical elements. Indeed, of the 80 or more elements known to the chemist, only 14 are commonly present in plants. Of these, at least 10 are absolutely necessary for plant growth. These are: carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium and iron. Sodium, silicon, chlorin, and manganese are usually found in plants and may be essential to their growth. Iodine also is present in some plants. Except in the two instances which will be noted later, plants cannot use for food the uncombined elements, such as metallic iron or carbon in the form of charcoal, but they are nourished by water, carbon dioxid (carbonic acid gas), and mineral salts—all of which are compounds containing the elements in chemical combination.

Water, composed of hydrogen and oxygen, is the largest single component of plants, forming from 75 to 90 per ct. of their fresh weight. It serves a double purpose in plants. Some of it is used as food, while the rest serves as the carrier of plant food. Only when it is dissolved in the watery sap can plant food be taken from the soil by the roots or be carried from one part of the plant to another. The plant obtains practically all its water from the soil thru its roots, only a small amount being taken from the air by the leaves. Soil water, absorbed by the roots, enters the cells of which the plant is composed and passes onward and upward thru the stem, moved by capillarity and sap currents, eventually reaching

every portion of the structure, being especially abundant in the leaves and growing parts. A surprising amount of water is needed by plants during growth. For every pound of dry matter which they manufacture, from 200 to 500 lbs. of water are drawn from the soil in humid climates, and as high as 1,800 lbs. in arid districts.

Next to water, the great food material of plants is carbon dioxid, or carbonic acid gas (composed of carbon and oxygen). This is obtained from the air, ten thousand parts of which contain 3 to 4 parts by volume of carbon dioxid. About 28 tons of this gas rest over each acre of the earth's surface. The air, carrying this carbon dioxid, is taken into the leaves thru the innumerable minute openings on their under surfaces,



WHERE PLANTS SECURE THEIR FOOD

Plants obtain carbon dioxid from the air, and water, mineral matter, and nitrates from the soil. Legumes are able to use indirectly the nitrogen of the air. Plants give off water and free oxygen gas to the air thru their leaves.

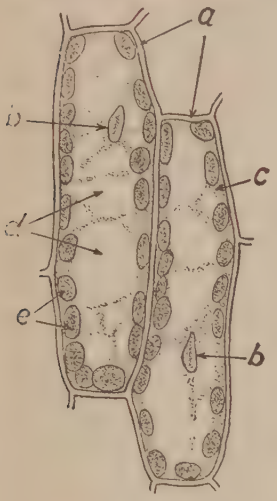
which lead inward among the cells of which the leaves are composed. The carbon dioxid is then absorbed by the cells and is used in building plant compounds, as described later. In producing a 12-ton crop of green corn over 4 tons of carbon dioxid are required, to obtain which the plants must take in about 10,000 tons of air. Yet the supply of carbon dioxid is never exhausted, for it is being continuously returned to the air thru the breathing out of carbon dioxid by animals and the decay of plant and animal matter.

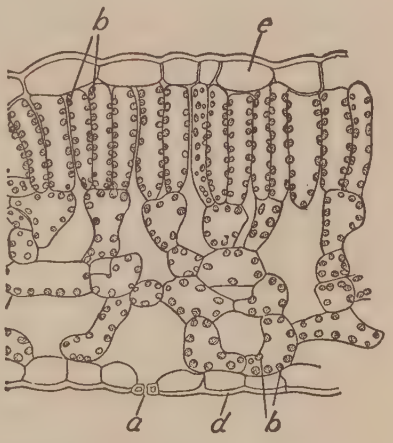
Nitrogen abounds in the living, growing parts of plants. Altho about three-fourths of the air is nitrogen gas, plants in general cannot use the free nitrogen of the air, but obtain their supply from nitrogen-containing

compounds in the soil, chiefly the nitrates. Bacteria living in nodules on the roots of legumes, such as clover, alfalfa, and peas, are able to take nitrogen gas from the air and pass it on in combined form to the host plants. Thus, the legumes are able indirectly, thru the aid of these bacteria, to use the nitrogen of the air as food.

Oxygen, which is a part of all plant compounds, is nearly all obtained from water and carbon dioxid, and not from the free oxygen gas of the air. Some oxygen gas is, however, being continuously absorbed by all green plants and is necessary for their growth.

The *mineral substances* required by plants are taken from the soil thru the roots. They include sulfur, phosphorus, potassium, calcium,





Left—Plant Cells, Magnified 350 Times

A, Cell wall; b, nucleus, or life center of cell; c, strands of protoplasm; d, spaces filled with cell sap; e, chlorophyll bodies. (After Strassburger.)

Right—Section of Leaf, Magnified 400 Times

A, Stoma, or opening on under side of leaf thru which air enters; b, chlorophyll bodies in leaf cells; d, lower epidermal cells of leaf; e, upper epidermal cells of leaf. (After Strassburger.)

magnesium, and iron. The plant can not use these mineral elements in an uncombined form for food, but only when built up into mineral salts, such as sulfates, phosphates, nitrates, and chlorides, of potassium, calcium, magnesium, and iron.

Sulfur, in small amount, is a component of plant proteins. Phosphorus, likewise in small amount, is present in the life-holding protein of the leaf cells and also abounds in the protein of seeds. Potassium is necessary in the formation of starch and sugar by plants. Magnesium is an essential part of chlorophyll, the green coloring matter of plants, which is necessary for their growth, and iron is also needed in its formation. Calcium is vital to plants, tho its use is not well understood. So-

dium, silicon, chlorin, and manganese, tho commonly present, are regarded by some authorities as not essential to plant life.

8. Plant building.—Living matter is distinguished from non-living matter by its power to grow, to repair its own waste, and to reproduce itself. In plants the life principle is most in evidence in the transparent, viscous protoplasm found within the plant cells. Because of inherent differences in the protoplasm, each plant possesses an individuality and is able to grow and reproduce itself after its own manner.

It has already been mentioned that carbon dioxid is absorbed by the leaf cells from the air entering the pores on the under surface of the leaves. Water and likewise nitrates and other mineral compounds taken by the roots from the soil are brought to the leaves in the sap currents. Here, in some mysterious manner the first plant compounds are built by the protoplasm of the leaf cells thru the action of sunlight on the green-colored chlorophyll of the leaf. In this process the carbon dioxid and water are broken down, and the carbon, hydrogen, and some of the oxygen of which these compounds are composed are rearranged or built into relatively simple plant compounds. The rest of the oxygen is given back to the air as free oxygen gas. It is not definitely known whether the first product so formed is starch, sugar, or some simpler compound.

From the compounds first made the plant builds more complex substances, some of which contain mineral matter obtained from the soil. Both sugar and starch contain much energy, which may be set free as heat when these substances are burned or otherwise broken up. Carbon dioxid and water, on the other hand, have little internal energy, and so on being decomposed, do not liberate heat. To make sugar and starch from these two energy-poor substances, the plant must receive energy from some outside source. This energy, used in building carbon dioxid and water into energy-holding sugar and starch, comes from the sunlight which is absorbed by the leaves.

9. The carbohydrates.—Sugar and starch, together with the related products, the celluloses and pentosans, are called carbohydrates. This group of plant compounds makes up the major portion of all plant substance. The term *carbohydrates* means that these compounds are formed of the three elements, carbon, hydrogen, and oxygen, the latter two being present in the proportion existing in water, the chemical formula for which is H_2O. (This means that every molecule of water contains two atoms of hydrogen and one atom of oxygen.) The molecular composition of the leading plant carbohydrates is as follows:

Glucose Fruit sugar	$C_6H_{12}O_6$	Starch Cellulose	$(C_6H_{10}O_5)x$
Cane sugar Malt sugar	$C_{12}H_{22}O_{11}$	Pentose Pentosan	$C_5H_{10}O_5$ $(C_5H_8O_4)x$

The molecules in the bracketed groups are in reality far more complex than the formulae indicate, the actual molecule being many multiples of the groups here given.

The *sugars,* which are the simplest of the carbohydrates, are all more or less sweet in taste and are soluble in water. Because they are soluble, they can be carried in solution in the sap of plants to all parts as needed. Thus they are the portable, carbohydrate building material of plants. Tho most plants store their reserve food in the form of starch, some plants store sugar instead.

The most common *simple sugars* found in plants are *glucose,* called dextrose by the chemist, and *fruit sugar,* also called fructose or levulose. These sugars have the formula, $C_6H_{12}O_6$, there being 6 atoms of carbon in each molecule. They are therefore called the 6-carbon sugars, or *hexoses.* Both occur in the juices of plants.

Compound sugars are formed in plants by the union of two molecules of simple sugars and the elimination of a molecule of water. The most common is *cane sugar,* or sucrose, which is made from one molecule of glucose and one of fruit sugar. Some plants, as the beet and the sugar cane, store their reserve food in the form of cane sugar. Another compound sugar, *malt sugar,* or maltose, is formed by the union of two molecules of glucose. *Milk sugar,* or lactose, a third compound sugar of this class, is not found in plants but is one of the chief components of milk. A compound sugar formed by the union of three molecules of simple sugars is found in certain plants.

STARCH GRAINS

A, From corn grain; b, from wheat; c, from oats; d, from potato. (Magnified 330 times.)

Starch, one of the most important carbohydrates of plants, is insoluble in water and is formed by the union of many molecules of glucose, with the elimination of water as a by-product. It is thus of much more complex composition than the sugars. Most plants store their reserve food chiefly as starch, which is deposited in the form of starch grains. Starch therefore abounds in nearly all seeds, forming over 70 per ct. of the dry matter in corn and wheat grains. Often starch is stored in the underground parts of plants, as in the potato tuber, or in fruits, as in the apple. Since starch is insoluble in the sap of plants, it must be changed into sugars by an enzyme, or ferment, when it is needed in other parts of the plant. For example, in a germinating seed the stored starch is gradually changed into sugar, and this is carried to nourish the various parts of the growing plantlet. (**37**)

Cellulose, an insoluble, resistant carbohydrate of still more complex nature than starch, is formed by the plant thru the union of a great

number of molecules of glucose. It is the common structural substance of plants, forming the chief part of the walls of the cells of which they are composed. The thickness of the cell walls, and consequently the percentage of cellulose, varies greatly in different parts of plants, the walls being thick and resistant in the woody stems, and thin and delicate in the softer parts, such as the fruits and leaves. Especially in the woody parts of plants, the cell walls do not consist merely of pure cellulose, but of cellulose combined with other related carbohydrates, which are even tougher and more resistant. In analyzing plants the chemist includes cellulose and these other compounds under the term *fiber*.

The *pentoses* are sugars which are similar to glucose and fructose but have 5 atoms of carbon in the molecule, in place of 6. The pentoses themselves do not commonly occur in plants, but the *pentosans*, which are formed from them in the same manner as starch is formed from glucose, are widely distributed. Pentosans are found in largest amounts in the more woody portions of plants and in the outer portions of seeds. While corn grain contains less than 6 per ct. of pentosans, usually straw and hay from the grasses contain over 20 per ct. and wheat bran about 24 per ct.

10. Fats and oils.—In some cases the plant stores reserve food in the form of fat, which is solid at ordinary temperatures, or of oil, which is liquid. Such storage is entirely possible, since fats and oils are formed from the same elements that make up the carbohydrates; i. e., carbon, hydrogen, and oxygen. Fats and oils are commonly included under the general term "fats".

Fats are formed in plants by the union of compounds called *fatty acids* with *glycerin*. The proportion of oxygen is much less, and of carbon and hydrogen much greater than in the carbohydrates, as the following formulae of three common vegetable fats show:

Stearin $C_{57}H_{110}O_6$ Palmitin $C_{51}H_{98}O_6$ Olein $C_{57}H_{104}O_6$

Due to the fact that they contain a larger proportion of carbon and hydrogen than the carbohydrates, the fats give off more heat on burning, one pound of fat producing about two and a quarter times as much heat as a pound of carbohydrates. Oils and fats most abound in the seeds of plants, the reserve food supply in peanuts and flax seed, for example, being stored largely in this condensed form. When seeds containing oil, such as the flax seed, begin to grow, the oil is changed over into products which nourish the growing plantlet the same as is done in ordinary seeds by the sugar which is formed from the stored starch.

Under the general class of *fats* there are included, in addition to the true fats or oils, other compounds somewhat similar to the fats in their properties. Among such compounds are the lecethins (phosphorus containing substances) and the waxes. These are present in but small amounts in feeds and need no special consideration in the feeding of stock.

11. Nitrogenous compounds.—We have learned how in the life-holding protoplasm of the green parts of plants, especially their leaves, the carbohydrates and fats are formed from the elements of carbon dioxid and water by the energy of the sun. To these life centers, with their green coloring matter, holding sugar and starch, the sap brings nitrates and other mineral salts gathered by the roots from the soil. Thru the union of the elements of the nitrates and other salts with those of the starches and sugars, there is formed a new group of complex compounds called *crude proteins*, which, in addition to carbon, hydrogen, and oxygen, found in the carbohydrates, contain nitrogen, sulfur, and sometimes phosphorus. These nitrogenous compounds are the most complex of all plant substances. For example, the following are given as the probable molecular composition of legumin, a protein found in the seed of the field pea, and hordein, found in the barley grain:

Legumin $C_{718}H_{1158}O_{238}N_{214}S_2$
Hordein $C_{675}H_{1014}O_{194}N_{181}S_4$

On account of this great complexity and also because of the great number of different nitrogenous compounds found in plants, these compounds are the most difficult of all plant substances to study and classify. For years able chemists have been attacking these intricate problems with great energy and patience. But even yet, altho much valuable information has been gained, our knowledge of the differences in the composition of the various nitrogenous compounds and their relative feeding values is limited. For this reason, in discussions of feeding stuffs and of the nutrition of animals these compounds are grouped under the general classes of *crude protein, proteins,* and *amids.*

Crude protein is the term employed to designate all the nitrogenous compounds of the plant. The chemist finds that about 16 per ct. of the plant proteins is nitrogen. Accordingly, he multiplies the nitrogen found in a given plant substance by 6.25 (100÷16=6.25) and calls the product crude protein. Crude protein embraces two great groups of nitrogenous plant compounds—*proteins* and *amids.*

Proteins are the more complex and highly organized forms of crude protein. They are not always soluble and therefore in many cases not transportable in the juices of the plant. The proteins form the basis of the living protoplasm of all plants and animals, and so are essential to all life.

Amids are the more simple compounds included in the crude protein. They may be termed the building stones of the proteins, for from them the plant constructs the more complex proteins, and on decomposition the proteins are again broken down into these more simple bodies. These compounds are the portable nitrogenous building compounds of the plant, for they are soluble in its juices and hence may be conveyed wherever needed thruout the plant structure. Commonly included under

the general term amids are compounds which the chemist calls *amino acids,* and others which he terms *true amids.* In this work, unless otherwise stated, amids will be used to denote both classes of substances.

The complexity of the proteins is evident from the fact that 18 different amino acids have already been identified, which may enter into their composition. Just as the letters of the alphabet may be combined into innumerable words, so the possibility for the combination of the amino acids into different proteins is almost limitless. Thus far, scores of different plant and animal proteins have been separated and examined by the chemists. Some of these, such as egg albumin, contain all the known amino acids, while others, as zein of corn and gliadin of wheat, lack one or more of them. As will be shown later, such incomplete proteins may have a lower value for animal feeding than those which are complete in their composition.

During the period of the plant's life when active growth is taking place, amids are constantly being formed in the living protoplasm out of the nitrates and other mineral salts and the elements composing sugar or starch. These amids are continually being transported to needed points and there changed into the proteins, and as a consequence do not usually accumulate in the plant. Just as starch and sugar may be changed one into the other in the plant, so the proteins and amids may be changed one into the other as plant necessity may require. When germination starts in a seed, an enzyme, or ferment, contained therein acts upon the insoluble proteins stored in and about the germ and changes them to soluble amids, so that the nitrogen may be transported to the newly forming parts of the plantlet. (37) When corn forage is placed in the silo, much of the protein it then contains is changed back to amids thru the fermentations which occur.

The life processes of both plants and animals are in general carried on and maintained thru the nitrogenous or protein compounds. This fact makes this class of substances of especial interest and practical importance to the farmer and stockman. The active protoplasm in all plant and animal cells and also the central nucleus, which controls the activity of each cell, are chiefly protein in nature. In plants the greater portion of the crude protein is always concentrated in the actively growing portions, such as the leaves, and in the reproductive parts, such as the germs of seeds.

12. Mineral matter.—It has already been pointed out in this chapter that certain mineral constituents, namely, sulfur, phosphorus, potassium, calcium, magnesium, and iron, are necessary in the formation of proteins and other complex plant compounds. All these mineral constituents are taken in solution from the soil by the roots and carried in the sap to the parts of the plant where needed. Mineral matter is found in small amounts thruout the plant, but the leaves contain more than the other parts, due to the life processes within the leaf cells and the constant evaporation of water from their surfaces by which the

ash in solution is left behind. The ash content of the bark of trees and stems of plants is also usually high.

13. The end of plant effort.—If we study the life history of a plant, we observe that its first effort is toward self-establishment and enlargement. At this time all the elaborated material, as fast as formed, is transferred to the growing parts that they may be built up and established. As the plant approaches maturity, its energies are changed from growth to reproduction, or the perpetuation of its kind. The nutrients in the juices, which were formerly directed to the growing portions, are now turned toward the reproductive parts. First come the blossoms, then the young enlarging fruits. Into these the sugars, amids, and mineral substances, all elaborated and worked over by the plant in its leaves, are poured in a steady current. The wheat plant resulting from a single kernel bears a hundred fruits in the shape of seed grains, while the Indian corn plant may produce a thousand-fold. In each of these grains is a miniature plant, the germ, composed largely of protein, about which is stored a generous supply of rich nutriment—proteins, starch, sugar, oil, and mineral matter—all in compact, concentrated form, awaiting the time when the germ shall begin life on its own account.

14. Plants support animal life.—It is Nature's plan that plants shall use energy supplied by the sun in building inorganic matter taken from earth and air into organic compounds. In this process the sun energy employed becomes latent, or hidden. Animals can not directly secure from the sun the energy necessary for their life but must live on the organic compounds built by plants. After more or less change during digestion, these compounds are built into their body tissues or are broken down within their bodies to produce heat and energy. In the coal burning in the grate, there reappears the energy of the sun which was stored in the plants of ages ago. In a similar manner the energy received from the sun by plants during their growth is transformed into animal heat and energy. Plants are thus sun-power machines for furnishing food to support animal life.

II. How the Chemist Groups Plant Substances

As we have seen, many different compounds are formed in plants, some of these being so complex that their exact structure has not yet been determined. In studying feeding stuffs it is desirable to group all plant compounds into a few classes, the amounts of which can be readily found by chemists. Accordingly, in analyzing plant materials and feeding stuffs, the following classes or groups of substances are commonly determined: water, ash or mineral matter, crude protein, fiber, nitrogen-free extract, and fat. The average percentages of these in typical feeds are shown in the following table, which is taken from Appendix Table I. The last column gives the number of analyses from which the average composition has been computed by the authors.

Chemical composition of typical feeding stuffs, from Appendix Table I

Feeding stuff	Inorganic matter		Organic matter				No. of analyses
				Carbohydrates			
	Water	Ash	Crude protein	Fiber	N-free extract	Fat	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Concentrates							
Dent corn	10.5	1.5	10.1	2.0	70.9	5.0	440
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490
Wheat	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat bran	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Linseed meal, old process	9.1	5.4	33.9	8.4	35.7	7.5	714
Roughages							
Timothy hay	11.6	4.9	6.2	29.8	45.0	2.5	221
Red clover hay	12.9	7.1	12.8	25.5	38.7	3.1	76
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Kentucky bluegrass, green	68.4	2.8	4.1	8.7	14.8	1.2	32
Corn silage, recent analyses	73.7	1.7	2.1	6.3	15.4	0.8	121
Mangels	90.6	1.0	1.4	0.8	6.1	0.1	38

15. Water.—To determine the amount of water in a feed the chemist places a small quantity of the material, finely divided, in a dish and ascertains its weight. It is then dried in an oven at a temperature of 212° F. for several hours and again weighed. The difference between the first and last weights represents the amount of water in the sample. Volatile compounds, such as some of the substances which give various plants their characteristic odors, are also driven off by this heating, but the weight of such compounds is generally insignificant.

From the second column of the table we learn that even such "dry" feeds as corn, oats, wheat, and wheat bran contain 9 lbs. or more of water per 100 lbs. of the feeding stuff. Timothy and clover hay contain still more water, and such succulent feeds as pasture grass, corn silage, and mangels are largely water.

16. Ash, or mineral matter.—The chemist next burns the sample and finds the weight of ash, or mineral matter, which is left. From the third column of the table we learn that 100 lbs. of corn or wheat contain less than 2 lbs. of ash. Oats, with their strawy hulls, and wheat bran, consisting of the outer coats of the wheat grain, carry more ash. The hays and straws are higher in ash than such grains as corn or wheat, due to the accumulation of mineral matter in the leaves during growth, to earthy matter washed upon the growing plants by rain, and to dust settling on the roughage before it is housed. Such foreign material is not really plant ash, but of necessity is reported as such. Owing to their high water content, the ash in 100 lbs. of fresh grass, silage, and mangels is low.

The ash and water of plants together constitute the so-called *inorganic matter;* the other components—crude protein, carbohydrates and fat—are termed the *organic matter.*

17. Crude protein.—The process of determining the nitrogenous constituents of feeding stuffs is too complicated for presentation here. Suffice it to say that the nitrogen content is found, and the result multiplied by 6.25 to give the crude protein, since about 16 per ct. of plant protein is nitrogen (100÷16=6.25). From the table we learn that 100 lbs. of wheat bran contains 16.0 lbs. of crude protein, while the amount in wheat is 12.4 lbs. and in dent corn only 10.1 lbs. per 100 lbs. Red clover hay contains over twice as much crude protein as timothy hay.

18. Fiber.—The woody portion of a feeding stuff is determined by boiling a sample thereof successively in weak acid and alkali and washing out the dissolved matter. That which remains is termed *fiber.* As is shown later (**48**), fiber, which consists mostly of cellulose, is less digestible and hence has a lower nutritive value than the other nutrients of feeding stuffs. Corn contains but 2.0 and wheat only 2.2 per ct. of fiber, while, owing to the woody hulls, oats contain 10.9 per ct. Roughages, especially the straws, are much higher in fiber than the concentrates. Mangels contain but 0.8 per ct. fiber; were they dried to the same water content as oats they would contain only 7.7 per ct. fiber—less than oats.

19. Fat.—A sample of the pulverized dried feed is treated with ether, which dissolves the fats, waxes, resins, chlorophyll, or green coloring matter, and similar substances. This, called *ether extract* in works on plant analysis, is for convenience termed *fat* in this work. The ether extract of seeds is nearly all true fat, or oil, while that of the leaves and stems of plants contains much chlorophyll, wax, etc. Corn and oats carry more fat than the other cereals. Some seeds, such as flax seed, are so rich in oil that it may be extracted from them by crushing and subsequent pressure.

20. Nitrogen-free extract.—The *nitrogen-free extract,* expressed in the tables in this book as *N-free extract,* embraces the substances that are extracted from the dry matter of plants by treatment with weak acids and alkalies under standard conditions, less the crude protein, fat, and ash. It is determined by difference and not by direct analysis. The total dry matter in a feeding stuff minus the sum of the ash, crude protein, fiber, and fat, equals the nitrogen-free extract. It includes the sugars, starches, pentoses, non-nitrogenous organic acids, etc., of the plant, and in addition some of the more soluble portions of the cellulose and pentosans. The nitrogen-free extract is more soluble and hence more digestible than the fiber, and thus has a higher nutritive value. (**48**) Over 70 per ct. of both corn and wheat is nitrogen-free extract, chiefly starch. The roughages, carrying much woody fiber, contain less of these more soluble carbohydrates than the concentrates.

21. Carbohydrates.—By the preceding methods of analysis, the carbohydrates are separated into the two classes: fiber, which is the part

having lower feeding value; and nitrogen-free extract, which is easily digested and hence has much higher value.

22. Concentrates and roughages.—These terms are used to differentiate feeds of a coarse, bulky nature from those which are more condensed and nutritious.

Concentrates are feeding stuffs of condensed nature, which are low in fiber and hence furnish a large amount of digestible matter. Examples of this class of feeds are the various grains, such as Indian corn, wheat, and oats, and milling by-products of high feeding value, such as wheat bran, linseed meal, gluten feed, etc.

Roughages are the coarser feeding stuffs, which are higher in fiber and supply a lower percentage of digestible matter. Such feeds as hay, corn fodder, straw, and silage belong to this class. Some of the low-grade milling by-products, such as oat hulls, ground corn cobs, and peanut hulls are roughages, rather than concentrates, for they are largely fiber and furnish but little nutriment. Roots are watery and bulky, and contain relatively little nutriment per pound, yet based on the composition of their dry matter they are more like concentrates than roughages, as they are low in fiber. They are really watery, or diluted, concentrates, tho for convenience they are included under fresh green roughages in Appendix Table I.

III. The Study of an Acre of Corn

The great basic facts in plant life, briefly set forth in the preceding pages, are admirably illustrated by a study of Indian corn, the greatest of our agricultural plants, such as has been made by Ladd at the New York (Geneva) Station[1] and Jones at the Indiana Station[2].

23. Changes in a growing corn crop.—Analyzing the plants at various stages from July 24, when they were about 4 feet high, until Oct. 8, when the kernels were hard, Jones secured the data which are given in the table on the next page. These figures are based on an average stand of 10,000 stalks per acre.

From July 24, at a stage when sometimes fed as soilage, to Aug. 28, when the silks were drying, the crop increased over 19,000 lbs. in total weight and nearly 4,000 lbs. in dry matter. The increase was thereafter less rapid, the total weight reaching the maximum when the kernels were in the milk stage. After this it decreased by over 4,000 lbs., due to the drying out of the crop as it matured. The dry matter, however, continued to increase rapidly until the plants were fully ripe. Indeed in less than a month following Aug. 28 the acre of corn stored over 3,000 lbs. of dry matter!

[1]N. Y. (Geneva) Rpt. 1889.
[2]Ind. Bul. 175.

NUTRIENTS IN CORN PLANTS AT VARIOUS STAGES

The shaded areas in the legend represent the amounts of crude protein, fiber, nitrogen-free extract, and fat in corn plants at various stages. Note especially the large storage of nitrogen-free extract as the crop matures. (From Indiana Station.)

THE SILO CONSERVES THE FULL VALUE IN THE CORN CROP

When the corn crop is ensiled at the proper stage of maturity, the full value of both grain and stover is secured for dairy cattle, beef cattle, and sheep.

INDIAN CORN—THE KING OF THE CEREALS

On millions of farms the success of animal husbandry depends largely on corn. Corn grain is an excellent example of a concentrate, for it is very low in fiber and furnishes a large amount of digestible matter.

LEGUME HAY—UNEXCELLED AS A DRY ROUGHAGE

Fortunate indeed is the farmer who has provided bounteous crops of choice legume hay for his stock. Clover or alfalfa hay is a roughage, for it is relatively high in crude fiber, but it is a roughage of the highest value, because it is rich in crude protein and mineral matter.

Composition of an acre of Indian corn at different stages

Stage of growth	Total wt. of green crop	Dry matter in crop	Ash	Crude protein	Fiber	N-free extract	Fat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Four feet high, July 24	5,138	731	90	149	170	282	40
First tassels, Aug. 6	18,827	2,245	195	360	670	977	42
Silks drying, Aug. 28							
Corn and cob	4,839	755	24	102	147	473	9
Stalk, blade, etc	19,488	3,812	248	334	1,056	2,133	40
Total	24,327	4,567	272	436	1,203	2,606	49
Milk stage, Sept. 10							
Corn and cob	7,288	2,268	50	252	263	1,648	55
Stalk, blade, etc	19,422	3,906	278	292	1,098	2,198	40
Total	26,710	6,174	328	544	1,361	3,846	95
Glazing stage, Sept. 24							
Corn and cob	8,620	3,866	66	346	312	2,985	158
Stalk, blade, etc	17,130	4,238	323	220	1,211	2,440	44
Total	25,750	8,104	389	566	1,523	5,425	202
Silage stage, Oct. 1							
Corn and cob	9,292	4,625	72	450	324	3,600	179
Stalk, blade, etc	15,983	4,304	297	210	1,278	2,484	36
Total	25,275	8,929	369	660	1,602	6,084	215
Ready to shock, Oct. 8							
Corn and cob	9,259	5,186	76	492	368	4,027	223
Stalk, blade, etc	12,994	4,226	307	199	1,369	2,309	42
Total	22,253	9,412	383	691	1,737	6,336	265

When four feet high the crop was nearly 86 per ct. water and only about 14 per ct. dry matter, while when the kernels were hard and the husks dry over 42 per ct. was dry matter. On Aug. 28 less than 17 per ct. of the total dry matter was in the ears; by Oct. 8 the ears contained over half the dry matter in the total crop.

24. Ash or mineral matter.—The total ash increased rapidly until the plants reached full height. During the period of greatest starch formation, Aug. 28 to Oct. 1, the increase in potash was especially rapid.

25. Crude protein.—The most rapid increase in crude protein, the nitrogenous portion, occurred before the plants were tasseled, when cell growth was more active. Ladd found that after the ears were silked, the amids—the building stones of the proteins—did not increase, while there was a steady and marked storage of proteins up to maturity. Altho amids were being constantly formed during the growth and development of the plants, they were in turn quickly built up into the more complex proteins. At all stages of growth nearly all the amids are in the stalks and leaves, the amids in the ears never exceeding 1.5 lbs. per acre, according to Jones. At maturity, Oct. 8, over 71 per ct. of all the protein in the crop was stored in the ears, principally in and about the germs of the kernels, ready to carry on the vital functions

whenever the grains might find lodgment in the soil and begin growth to form new corn plants.

26. Fiber.—The stalks of corn must be strong and sturdy to carry the abundant foliage and particularly the heavy ear—hence the increase in fiber, the woody framework of the plant, which was especially rapid till the skeleton of the plant was grown.

27. Nitrogen-free extract.—The nitrogen-free extract, the most valuable portion of the carbohydrates, increased more than 2.5 tons between tasseling and ripening and amounted to 6,336 lbs. when the crop was mature. About 60 per ct. of this was starch, stored chiefly in the corn kernels. At the silk stage the crop contained only about 500 lbs. of starch, but after this it increased rapidly as the kernels filled and matured.

Tho the sugars were being steadily formed in the leaves of the plants, they did not increase to any material degree after the milk stage. As the sugars were formed they were continuously being transferred to other parts, especially the swelling kernels of the ear. Here a large portion was changed to starch and compactly stored about the germs to serve as food for the future plantlets. Another portion of the sugars was changed into cellulose to form the woody framework of the plant structure. The elements of a third portion were combined with nitrates and other mineral matter from the soil to form the nitrogenous amids and proteins. The other soluble carbohydrates included in the nitrogen-free extract consisted chiefly of the more soluble pentosans and celluloses. These increased up to the glazing stage.

These studies show most clearly the heavy losses of valuable nutrients which are sure to occur when a crop of Indian corn is harvested too early. Formerly corn was often cut for silage before the kernels had started to glaze. This not only resulted in a great loss of feed, but also in a sour silage of only fair quality. As is pointed out in a later chapter, experience has shown that corn should not be ensiled until the kernels have hardened and glazed (with the dent varieties, until the kernels are well dented). The crop should, however, be cut for silage while most of the leaves are yet green and succulent. (299)

CHAPTER II

COMPOSITION OF THE ANIMAL BODY—DIGESTION—METABOLISM

I. Composition of the Animal Body

In gaining a knowledge of the feeding of live stock it is necessary to understand clearly of what substances the bodies of farm animals are composed. In the preceding chapter we have studied the composition of plants and the manner in which the plant compounds are formed. Let us now consider the nature and composition of the bodies of farm animals, which are built up and nourished by plants.

28. The animal body.—The unit of the animal body is the life-holding cell, which, associated with myriads of others and modified in innumerable ways, makes up the body structure. In studying the higher animals we may regard their bodies as consisting of a bony skeleton surrounded by an elaborate muscular system. Fatty tissue permeates the bones and muscles, filling in and rounding out the body form, and around all is the enveloping skin. Within the body cavity are the various special organs, such as the heart, stomach, etc., designed for dissolving, assorting, distributing and utilizing the nutritive material of the food and for conveying and disposing of the waste.

Protein makes up a much larger part of the dry matter in the bodies of animals than in plants. Contrasted with plant cells, in which the cell wall is made of cellulose, the cell wall or membrane in animals is protein. The muscles, which make possible the movements of the body, the nerves and brain, which control and direct all body activities, and also the various internal organs are chiefly composed of protein. Protein also makes up the cartilages in the body, the network of connective tissue thruout the muscles and organs, and such epidermal or outer tissues as the skin, hair, wool, feathers, hoofs, nails, and horns. The bones also contain considerable protein. About two-thirds of the weight of dry bones from which the fat has been extracted consists of mineral matter, which gives them their hardness and density, and the remainder of protein, which makes them elastic and tenacious. By soaking a fresh bone in weak hydrochloric acid the mineral matter may be dissolved out, leaving the protein and other organic parts. While the original shape of the bone will be retained, the mass, which consists chiefly of protein, will be soft and flexible, like India rubber.

Fats form the chief part of the fatty or adipose tissues of the body and are also distributed in smaller amounts thruout most other parts. The animal body stores nearly all its reserve food in the form of fat,

while plants, as we have learned, commonly store their reserve food in the form of starch.

Carbohydrates, which form such a large part of plants, make up but a very small portion of the animal body. As will be discussed later, altho the glucose in the blood and the glycogen, or animal starch, in the liver and other organs perform exceedingly important functions, at no time do they form an appreciable part of the animal's weight. (60)

Mineral matter forms the larger part of the bony skeleton, but is also distributed in small amounts thru all parts of the body, where it performs indispensable vital functions, which will be discussed later.

29. Composition of animals.—Over 60 years ago Lawes and Gilbert, famous English agricultural scientists, analyzed the entire bodies of several farm animals—a task involving much labor. During recent years similar studies have been made at certain of the American experiment stations. The following table,[1] which summarizes some of these investigations, shows that the composition of the bodies of farm animals varies greatly according to their age and degree of fatness:

*Composition of the bodies of farm animals**

	Water Per ct.	Protein Per ct.	Fat Per ct.	Ash Per ct.
Calf, wt. 100 lbs.	71.8	19.9	4.0	4.3
Calf, wt. 300 lbs.	65.7	18.8	11.2	4.3
Growing steer, wt. 700 lbs.	60.3	18.6	16.6	4.5
Partly fat steer, wt. 1,000 lbs.	52.0	17.1	26.9	4.0
Fat steer, wt. 1,200 lbs.	48.0	16.0	32.3	3.7
Very fat steer, wt. 1,500 lbs.	43.5	15.7	37.7	3.2
Fat lamb	52.3	13.4	31.2	3.2
Sheep, before fattening	61.0	15.7	19.9	3.4
Half-fat sheep	55.2	15.4	25.9	3.5
Fat sheep	46.2	13.0	37.9	3.0
Very fat sheep	37.1	11.5	48.3	3.1
Hog, before fattening	58.1	14.5	24.6	2.8
Fat hog	43.0	11.4	43.9	1.7

* Not including contents of digestive tract.

The table shows that 71.8 per ct. of the body of a 100-lb. calf is water and that the proportion of water steadily grows less as the animal matures and fattens, the body of a very fat 1,500-lb. steer containing only 43.5 per ct. water. The percentage of protein remains quite constant during growth but decreases as the animal fattens. On the other hand, the percentage of fat increases gradually during growth, and more rapidly while fattening. Over one-third of the carcass of the fattened 1,500-lb. steer is fat. The percentage of ash, or mineral matter, shows the least change, but decreases as the animal fattens, since the fatty tissue contains but little mineral matter.

Similar changes occur in the bodies of sheep and swine, as the animals mature and fatten. In general, sheep and swine at the same degree

[1] Data for cattle from Haecker, Minn. Bul. 193, and for sheep and swine from Lawes and Gilbert, Philosophical Transactions, 1859.

of fatness contain less water and protein and considerably more fat than cattle. The fat hog, for example, contains 43.9 per ct. fat and only 11.4 per ct. protein. Due to their small skeletons, the bodies of swine contain less ash than those of cattle and sheep.

30. Mineral matter.—The preceding table shows that mineral matter, or ash, at no time forms a large part of the body, as it ranges from only 1.7 per ct. in the fat hog to 4.5 per ct. in the growing steer. Yet, as will be pointed out later, mineral matter has exceedingly important functions in the animal body. Indeed, an animal will die sooner if given plenty of food, which has, however, been freed from mineral matter, than if given no food at all. (**95-101**)

The following table shows the principal mineral constituents in the bodies of the animals (fasted live weight) analyzed by Lawes and Gilbert, and also in milk and unwashed wool:

Mineral matter in 1,000 lbs. of farm animals, milk, and unwashed wool

	Lime (CaO) Lbs.	Phosphoric acid (P_2O_5) Lbs.	Potash (K_2O) Lbs.	Magnesia (MgO) Lbs.
Fat calf	16.46	15.35	2.06	0.79
Half-fat ox	21.11	18.39	2.05	0.85
Fat ox	17.92	15.51	1.76	0.61
Fat lamb	12.81	11.26	1.66	0.52
Sheep, before fattening	13.21	11.88	1.74	0.56
Fat sheep	11.84	10.40	1.48	0.48
Pig, before fattening	10.79	10.66	1.96	0.53
Fat pig	6.36	6.54	1.38	0.32
Milk	1.70	2.00	1.70	0.20
Unwashed wool	1.80	0.70	56.20	0.40

Because they form the chief mineral constituents of the bones, lime and phosphoric acid greatly exceed in amount the other mineral components of the body. Lime, the largest mineral constituent of the bones, ranges from about 6 lbs. per 1,000 lbs. of carcass in the fat pig to over 21 lbs. in the ox. Phosphoric acid almost equals lime in quantity, while there are only from 1 to 2 lbs. of potash per 1,000 lbs. of animal and still less magnesia. Soda, silica, iron, etc., are found in small amounts.

31. Plants and animals compared.—Two fundamental differences between plants and animals have already been pointed out: First, that the wall or membrane which surrounds the cells in the bodies of animals is formed of protein, while the cell walls in plants are made of cellulose; second, that in animals most of the reserve food is stored in the form of fat, while in plants reserve food is stored chiefly in the form of starch. The other main difference between plants and animals is that the higher plants are nourished by inorganic matter, while animals must live almost entirely upon organic matter.

Plants absorb thru their leaves great quantities of carbonic acid gas, composed of carbon and oxygen, retaining the carbon and giving off the oxygen as waste. Animals take free oxygen thru their lungs

and combine it with carbon to form carbonic acid gas, which is thrown off as waste in the breath. Thus the two great classes of life are interdependent.

In the animal body the organic material derived from plants may be built into still other highly organized compounds, usually protein in character. Thus built, matter has reached its last high stage of organized existence, and its fall or descent soon begins. In the daily waste of the body or upon the withdrawal of life, this highly endowed organic matter is broken down into inorganic compounds, to begin again the eternal round of Nature.

II. Digestion

To understand the value of various feeds for stock and appreciate the functions which they serve in the animal body, we must have clearly in mind the processes thru which the food taken into the body is so changed that it can be finally used for the various life functions.

32. Digestion.—The changes which food undergoes within the digestive tract of the animal to prepare it for absorption and ultimate use in building new tissues, repairing body waste, and as a source of energy are collectively known as *digestion*. Digestion is effected by enzymes, or ferments, produced by glands of the mouth, stomach, pancreas, and small intestine, and by the bile, secreted in the liver. Bacteria inhabiting certain parts of the digestive tract attack the woody cellulose of the food, breaking it down and thereby freeing nutrients. In addition to the action of the secretions and bacteria, the food in its course thru the digestive tract is subjected to mechanical processes which tend to reduce it to a fine state of division, the object of the whole process being to separate from the useless matter those constituents which are to nourish the body.

33. Nutrients.—In discussing stock feeding, it is necessary to understand clearly what is meant by each of the following terms:

The term *nutrient* is applied to any food constituent, or group of food constituents, of the same general chemical composition, that may aid in the support of animal life. Crude protein, the carbohydrates, and fat constitute the generally recognized primary classes of nutrients, altho air, water, mineral matter and vitamines might likewise be so termed.

The term *digestible nutrient* covers that portion of each nutrient which is digested and taken into the body. (69)

34. Concerning rations.—On the farm a *ration* is the feed allowed for a given animal during a day of 24 hours, whether all is fed at one time or in portions at different times.

A *balanced ration* is the feed or combination of feeds furnishing the several nutrients—crude protein, carbohydrates, and fat—in such proportion and amount as will properly nourish a given animal for 24 hours.

A *maintenance ration* is one that furnishes enough, but no more, of each of the several nutrients than is required to support an animal

which is doing no work and yielding no material product, so that it will neither gain nor lose in weight.

35. The alimentary canal.—The alimentary canal should be considered as a long, winding tube passing thru the animal from mouth to vent, enlarged in places for the storage of food or waste. It includes the mouth, gullet, stomach, small intestine, and large intestine. Within its linings are organs which secrete the various fluids of digestion, and into it, from other organs located near by, pour still other digestive fluids. Within its walls are nerves controlling its action, arteries which nourish it with fresh blood, and veins and lymphatics which absorb and carry from it the products of digestion. It should be borne in mind that the contents of the stomach and intestines are really outside the body proper. Only when a substance has passed into or thru the walls of the digestive tract has it actually entered the body of the animal.

Ruminants (animals which chew the cud), including the ox, sheep, and goat, have much more complicated digestive tracts than other animals. In the horse and pig the gullet, or esophagus, is a simple muscular tube passing from the mouth to the stomach. On the other hand, in ruminants the gullet is expanded just before the true stomach, or abomasum, is reached into three compartments of great aggregate capacity, the first of which is the paunch, or rumen; the second, the honeycomb, or reticulum; and the third, the manyplies, or omasum. Of the four stomachs the paunch is by far the largest, providing over 80 per ct. of the total capacity of all the stomachs in the full-grown ox. The inside lining of each compartment differs in appearance. The lining of the paunch is somewhat like coarse velvet, due to myriads of small projections; the honeycomb is so called on account of its honeycomb-like lining; and the manyplies is so named because its lining forms many folds or leaves.

The four stomachs of the full-grown ox have a combined capacity of 120 to 180 quarts or more. In young ruminants the first three stomachs are much less developed than in mature animals. For example, in a young calf, the abomasum will have a considerably larger capacity than the paunch, the honeycomb, and the manyplies, combined.

In the horse and the hog, the stomach is simple, consisting of but a single sac, much like the stomach of man. The stomach of the horse has a capacity of only 12 to 19 quarts, being small indeed compared with the capacity of the stomachs of the ox. The stomach of the pig holds about 8.5 quarts. The fourth stomach, or abomasum, of ruminants corresponds to the single stomach of these other animals.

The small intestine is the long, folded, winding tube into which the stomach empties. In the mature ox it is about 2 inches in diameter and 130 feet long, or about 20 times the body length. In horses it is 70 to 75 feet long, in sheep 80 feet, and in swine 60 feet. Its average capacity is about as follows: Cattle, 70 quarts; horses, 50 to 65 quarts; sheep and swine, 10 quarts.

The large intestine, into which the small intestine empties, is larger in diameter, but much shorter. In cattle the large intestine has a capacity of about 40 quarts, in sheep 6 quarts, and in hogs 11 quarts. In the horse, the part of the large intestine next to the small intestine, called the blind gut, or caecum, is greatly enlarged and the large colon, the second part of the large intestine, also is much larger than in cattle. Due to this, the large intestine in the horse has a total capacity of 120 to 140 quarts, partially making up for the small size of the stomach. Were it not for the great size of the caecum and of the large colon, the horse would be unable to consume and digest much hay or other roughage.

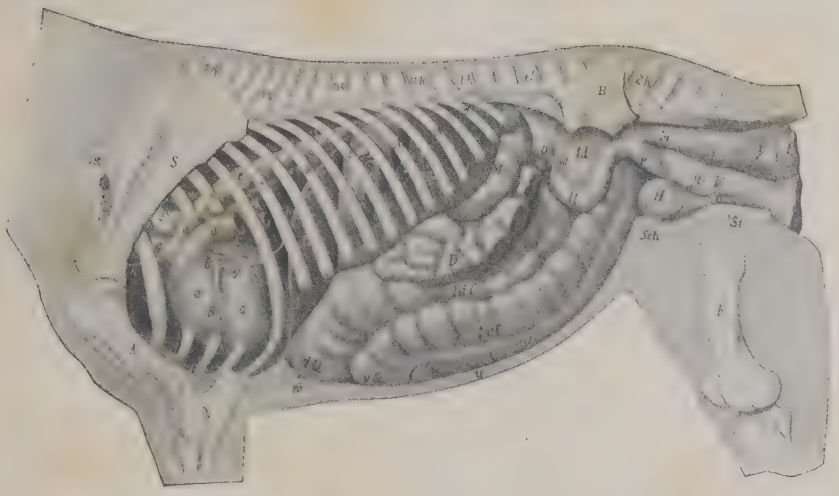
The pig has neither the four stomachs of the ruminants nor the large caecum of the horse and is therefore not well fitted to use large amounts of roughage. His large intestine, however, holds nearly twice as much as that of the sheep, which aids him somewhat in utilizing coarse feed.

36. Mastication.—In the mouth the food is crushed and ground by the teeth and at the same time moistened by the alkaline, somewhat slimy, saliva. In the mastication of food moist and slippery masses are formed which pass readily thru the gullet into the stomach. Exceedingly large amounts of saliva are secreted by the larger farm animals, especially when eating dry feed. For example, a horse may secrete as much as 90 lbs. during 24 hours. Colin[2] found that oats required a little more than their own weight, green fodders half, and dry hays or fodders four times their weight of saliva during mastication. The sensation of taste is largely dependent on the saliva, as it dissolves small amounts of food, which affect the nerves of the tongue that are concerned with this sensation.

Ruminants while eating chew their food only enough to moisten it, if dry, and form it into masses of suitable size to be swallowed. When hunger is satisfied they seek a quiet place, if possible, and proceed to return the food in "cuds" to the mouth, chewing each thoroly before reswallowing. The gullet of ruminants, which passes to the third stomach, or manyplies, also opens into the paunch and the honeycomb thru a slit (called the esophageal groove). This has an exceedingly important function in the process of rumination. The masses of solid food which ruminants swallow are usually so large as to distend the gullet. On coming to the slit they are therefore pressed out, just as would be the case if one tried to force thru a rubber tube with a slit an object which fitted it tightly. These masses of food are usually pushed into the paunch until it is full, and then into the honeycomb instead.

When the animal ruminates, or "chews the cud," the food is forced back to the mouth in masses, or "cuds," thru the same slit by contractions of the muscular paunch, the honeycomb, and of the gullet itself. The ox chews each cud of about 4 ounces for a little less than a minute, adding saliva until the finely divided material becomes more or less soup-like. On being reswallowed, this finely divided material may flow along

[2]Smith, Physiol. Domestic Animals, p. 286.



INTERNAL ORGANS OF MARE; LEFT VIEW

The organs of greater interest are as follows: L, Left lobe of liver; Ma, stomach, the posterior part of which is indicated by dotted line, x; Mi, spleen; l N, left kidney, concealed part of which is indicated by dotted line, n; M, small colon; D, small intestine, parts of which have been removed; l.d.c., l.v.c., v.d., and v.q., parts of colon; O, left ovary; U, horn of uterus; M, rectum; V, vagina; H, bladder; a, a′, b, b′, b″, c, d, and e, heart and arteries entering it. (From Sisson, "Anatomy of the Domestic Animals.")

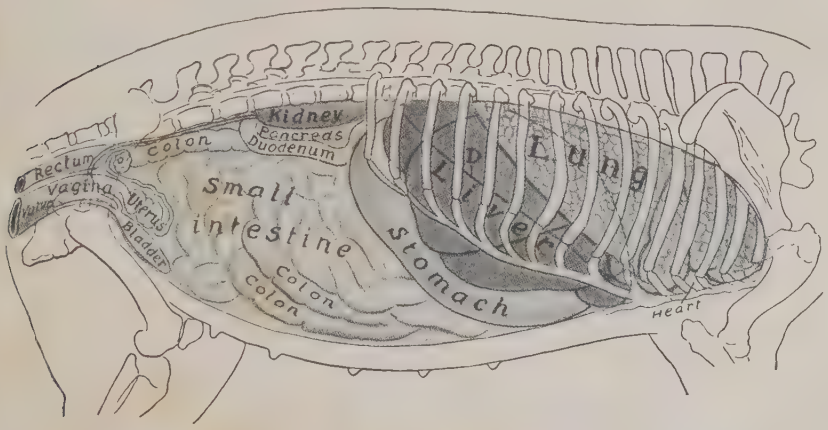
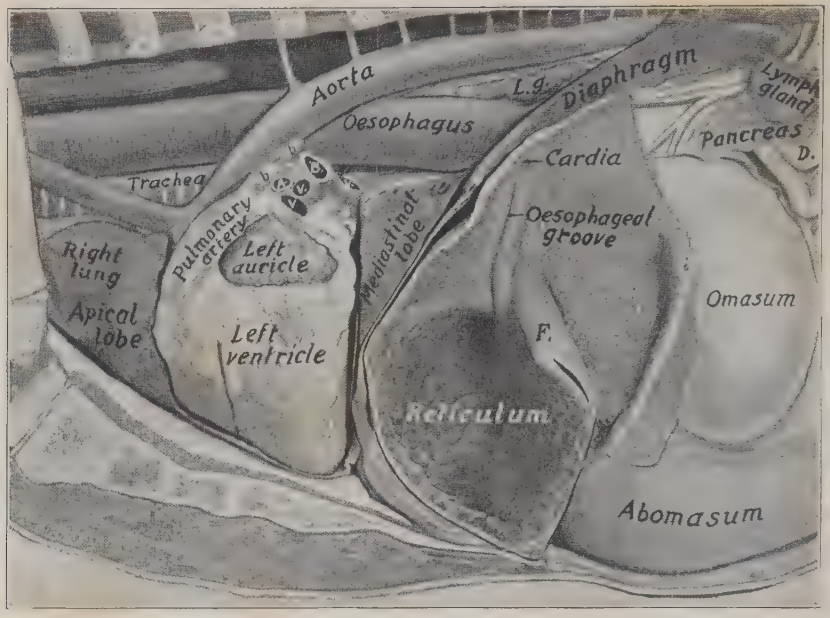


DIAGRAM OF DIGESTIVE SYSTEM OF PIG; RIGHT SIDE

The pancreas and duodenum are not in contact with the flank, as would be inferred from this figure, but are situated nearer the center of the body, and if viewed from the right side, would be covered by the small intestine. (From Sisson, "Anatomy of the Domestic Animals.")



THORACIC AND FRONT ABDOMINAL ORGANS OF OX

Most of the rumen has been removed, and the left wall of the reticulum cut away. A, Left pulmonary artery; B, left bronchus; V, V, V, pulmonary veins; L g, lymph gland; D, end of duodenum; F, fold between rumen and reticulum. (From Sisson, "Anatomy of the Domestic Animals.")

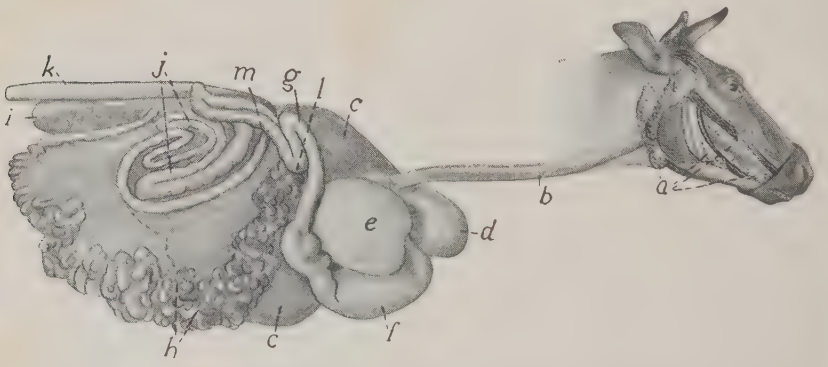


DIAGRAM OF THE DIGESTIVE TRACT OF THE COW

A, Salivary glands; b, gullet; c, paunch, or first stomach (only a small part of the paunch is here visible, the rear portion being hidden by the intestines); d, honeycomb, or second stomach; e, manyplies, or third stomach; f, fourth, or true stomach; g, duodenum, or first part of small intestine; h, mesenteric part of small intestine; i, caecum; j, colon; k, rectum; l, point of entrance of bile duct into duodenum; m, point of entrance of pancreatic duct into duodenum. The intestines are spread out somewhat in this diagram.

the gullet past the slit, and directly into the third stomach, from which it passes into the fourth or true stomach or it may re-enter the paunch and then pass on into the other stomachs. Water or liquid food may pass at once to the third stomach.

Animals do not ruminate during sleep, while working, when excited, or if in pain. The fact that the ox requires 7 to 8 hours daily for rumination handicaps him somewhat as a work animal, for if his hours of work are long he must dispense with sleep to masticate his food.

37. Enzymes.—Most of the changes which food undergoes in digestion are brought about by enzymes, and also most other body processes are dependent on enzyme action. (63) The general nature of enzymes should therefore be clearly understood.

Enzymes are mysterious organic compounds which are able to change or break down other organic compounds without themselves being changed or broken down. To illustrate the action of enzymes, we will take, as an example, *ptyalin*, the enzyme contained in the saliva, that converts the starch of the food, which is insoluble, into sugar, which is soluble. If starch is mixed with saliva and the whole kept at body temperature, the starch gradually dissolves, being changed to malt sugar. Thru the action of the ptyalin, the complex starch molecule has been cleaved, or split, into the simpler molecules of sugar. If starch is mixed merely with water, instead of saliva, this change will not occur.

The ptyalin is not itself altered by this process, for, if more starch is added and the resulting sugar removed, the process may be repeated many times. However, heating the enzyme above a certain temperature destroys it. At the freezing temperature its action ceases, tho the enzyme is not destroyed, for on warming it becomes active again. Ptyalin acts best in a neutral or slightly alkaline solution and is destroyed by the presence of much acid, while some other enzymes act only in acid solutions. Each of the enzymes of digestion is capable of acting on only one of the groups of nutrients; for example, on proteins, on carbohydrates, or on fats.

38. Digestion in the mouth.—Not only is the food prepared for swallowing in the mouth, but in most animals the first step in digestion occurs here, thru the action of ptyalin on the starch in the food. Recent investigations have shown that the saliva of cattle and dogs contains practically no ptyalin, and that of horses but little. The saliva of swine contains a fair amount, and that of man, monkeys, rabbits, rats, and mice has the greatest starch digesting power.

39. Digestion in the simple stomach.—With such animals as the horse and pig, which have simple stomachs, the food passes directly from the mouth, where it remains but a comparatively short time, thru the gullet to the single stomach. There it is acted on by the gastric juice, which consists of water containing the enzymes, pepsin and rennin, and from 0.2 to 0.5 per ct. of hydrochloric acid.

Pepsin, which acts only in weak acid solutions, converts the very complex proteins into soluble and simpler, tho still complex, products known

as proteoses and peptones. *Proteoses* and *peptones* are soluble nitrogenous compounds, simpler than the proteins from which they originate. They are the result of the partial cleavage of proteins with the addition of water.

Rennin, the other enzyme of the gastric juice, changes milk into a solid curd. This enzyme is an interesting provision of Nature for changing milk into a solid form so the animal may get the full value from it. Altho liquid, milk is not in condition to be taken directly into the animal system, but, like solid foods, must first undergo digestion. Milk being liquid, the stomach would naturally pass it quickly on to the small intestine, but if this occurred it would not be sufficiently acted on by the pepsin. Rennin quickly converts the milk into a solid curd which is easily retained by the stomach until dissolved by the action of the gastric juice. One part of rennin will coagulate 400,000 parts of milk. The rennet extract used in cheesemaking is made from the membrane lining the fourth stomach of young calves.

Acid destroys the power of ptyalin to convert starch into sugar. The stomach, however, is so constructed that the action of ptyalin on the food is not too promptly checked after the food reaches it. The first portion of the stomach, into which the gullet directly leads, secretes no acid. The action of ptyalin on the starches of the foods continues, therefore, in this part of the stomach. The intestinal or rear end of the stomach, on the other hand, secretes much hydrochloric acid. Here the action of the ptyalin ceases, and pepsin digestion becomes active. Only the preliminary steps of digestion are accomplished in the stomach, and only insignificant amounts of nutrients are absorbed from it. A slight digestion of fat may sometimes occur in the stomach, due to a fat-digesting enzyme.

Soon after the food reaches the stomach, that organ begins a series of orderly movements for the delivery of its contents into the small intestine. In this the stomach contracts at the middle region, and the wave of contraction proceeds slowly and regularly toward the intestinal end, one wave following another. When digestion has progressed to some extent, every time the contraction reaches the rear end of the stomach, the ring of muscles which keeps the stomach shut off from the small intestine relaxes and allows a small quantity of the semi-liquid contents of the stomach to spurt thru into the intestine. After this the ring of muscles again contracts, closing the entrance. The stomach in turn slowly relaxes, and after a certain length of time, varying in different animals, the process is repeated. By this means the fluid portions of the contents of the stomach are squeezed out and carried into the small intestine, while the more solid portions remain behind for further action by the gastric juice. In animals with a simple stomach little or no churning or mixing of the food is produced by the movements of the stomach. The contents are simply pushed gradually toward the intestinal end of the stomach by the waves of muscular contraction.

40. Stomach digestion of ruminants.—Tho the first three stomachs of ruminants secrete no enzymes, but only water, they are highly important in digestion. The nutrients of plants are enclosed within the cellulose cell walls, and where these are hard and thick, as in hay and straw, the digestive fluids can not easily reach and attack the nutrients locked within. As we have seen, when ruminants swallow solid food, it passes chiefly into the paunch. Here it is softened by the moisture, slowly but thoroly mixed by muscular contractions, and ground against the rough lining. All this prepares the food for easy digestion further on.

A considerable amount of actual digestion also occurs in these first stomachs, especially in the paunch, thru the action of certain bacteria. These bacteria attack the cellulose and pentosans of the feed and break them down with the production of heat and the formation of organic acids, chiefly acetic acid and butyric acid, and of gases, including methan (marsh gas), carbon dioxid, and hydrogen. The acids serve as food, the same as do the sugars, but the gases are useless and are excreted. This digestive action is highly important, for a large part of hay and other roughages consists of cellulose and pentosans (**9**), and Nature has provided no enzymes of the digestive tract which are able to digest these compounds. The ability of the animal to use them as food therefore depends on the fermentations caused by these bacteria. In this action the cell walls of the plant materials are broken down, setting free the nutrients contained within, so they can be more easily acted on by the digestive juices in the true stomach and the intestines.

Not only do the bacteria digest cellulose and pentosans, but also they may attack starch and sugar. This action is detrimental, for these nutrients would be digested more efficiently later on in the small intestine, while in the bacterial digestion a considerable part of their feeding value is lost thru the heat and gases produced in the fermentations. (**84**) When fresh, easily fermented forage, such as green clover or alfalfa, is eaten, the bacterial action may then be so great that gas is produced faster than it can be carried away, and "bloat" results. (**340**)

The fact that only a small amount of ptyalin is present in the saliva of the ox and sheep, or that it is entirely absent, as is claimed by some, is thus advantageous. If their saliva easily converted starch into sugar, a large amount of sugar would be formed in the paunch, which would then in turn be attacked by bacteria, with much resultant loss of nutriment. In addition to the digestion in the paunch caused by bacteria, more or less is also undoubtedly effected by the enzymes which are contained in some foods, such as the cereal grains, for the moisture and warmth of the paunch are favorable to enzyme action in general.

41. The small intestine.—When received into the small intestine, the partially digested food is a semi-liquid mass. As yet, the fats have not been digested appreciably, and the digestion of the proteins and carbohydrates is far from complete. Here the work of digestion proceeds even more vigorously than in the stomach, all classes of nutrients being

attacked. The small intestine receives near its upper part digestive fluids from two outside organs, the liver and the pancreas, and another digestive juice is secreted by the wall of the intestine itself. Immediately on entering the small intestine the inpouring material is changed from an acid to an alkaline character thru the rapid addition of bile and pancreatic juice, both alkaline. This stops the action of the pepsin, which works only when acid is present. The intestinal contents are moved along by waves of muscular contraction of the intestinal walls.

42. The pancreatic juice.—The *pancreatic juice* is produced by the pancreas, or sweetbread, a slender gland lying just beyond the stomach and connected with the small intestine by a duct or by two ducts in certain animals, as the horse. In some animals it is thin, clear, and watery and in others thick and slimy. The chief enzymes it contains are trypsin, amylase and lipase.

Trypsin, like pepsin, changes protein into proteoses and peptones, but is also able to split some of these partially digested substances into amino acids. It is believed that before the food protein can be absorbed and used by the animal body it must all be cleaved into amino acids, which, as has been previously shown (**11**), are the simple "building stones" from which the proteins are formed.

The digestion of protein brought about by trypsin in the small intestine is thus much more complete than that occurring in the stomach thru the action of pepsin. It is most interesting that trypsin is secreted by the pancreas in an inactive form, which will not digest protein. As soon as the pancreatic juice comes in contact with the intestinal wall, intestinal juice is produced, which contains a substance that changes the trypsin into the active digesting form.

Amylase, formerly called amylopsin, changes starch into malt sugar.

Lipase, formerly called steapsin, splits fats into fatty acids and glycerin. The fatty acids unite with the alkalies in the bile to form soaps, and are absorbed from the intestine in this form.

Ordinarily, when digestion is not going on in the small intestine there is no secretion by the pancreas. However, the secretion of this digestive fluid begins promptly after the partially digested food enters the small intestine from the stomach. This is brought about by the following action: The partially digested food as it enters the intestine is acid, due to the hydrochloric acid of the gastric juice. The acid acts on the lining of the small intestine, at once producing something which is absorbed into the blood and then causes the pancreas to pour forth the pancreatic juice just when needed, a forceful illustration of how the organs of the complicated digestive system work in harmony.

43. The liver.—The liver, the largest organ in the body, has several important duties in digestion and other vital processes. In addition to the secretion of bile, which is discussed in the following paragraph, the liver is a storehouse for carbohydrates (**60**), and has important functions in regulating the composition of the blood. It also protects the body

from various poisonous substances, either taken accidentally in the food or formed in the digestive tract thru putrefaction, doing this by uniting these substances with others to form compounds which are not poisonous.

Bile is a greenish or golden colored fluid, alkaline and extremely bitter in taste. In cattle, sheep, and swine the bile, as secreted, is stored in the gall bladder, whence it is poured thru a duct into the intestine. The horse has no gall bladder, the bile passing directly into the intestine as it is secreted. Bile contains no enzymes, but is nevertheless exceedingly important in digestion, as it furnishes the alkalies necessary to change the fatty acids formed by lipase into soaps, in which form they may be absorbed. It also aids in emulsifying the undigested fat; i. e., breaking it up into very minute droplets, so it will present a large surface and be more readily and rapidly acted on by the lipase. Moreover, it dissolves the fatty acids and soaps, so that they are more readily absorbed by the small intestine. After performing these important functions, the bile is not wholly excreted with the contents of the intestine, but is in part taken up by the circulation and utilized again. According to Colin, the liver of the horse secretes over 13 lbs. of bile during each 24 hours, of the ox 5.7 lbs., and of the sheep 0.75 lb.

In addition to its action on fats, bile stimulates the action of the pancreatic juice, checks putrefaction, and also aids in the passage of food thru the intestines by increasing the muscular contractions of the walls. Furthermore, in the bile there are excreted waste products which would be harmful if retained in the body.

44. The intestinal secretion.—The digestive fluid secreted by the mucous membrane of the small intestine contains several enzymes, the most important of which are erepsin and the invertases.

Erepsin, an enzyme of great digestive power, attacks the proteoses and peptones which have escaped the action of trypsin and breaks them up into amino acids. It can not act on protein which has not already been split into proteoses and peptones.

The *invertases* (sucrase, maltase, and lactase) change cane sugar, malt sugar, and milk sugar into the simpler glucose-like sugars.

Due to the vigorous action of the pancreatic juice, the bile, and the intestinal secretion, digestion is very thoro in the small intestine and under ordinary conditions little that is useful escapes digestion. Most of the digested matter is absorbed from the small intestine, thus entering the body proper, as is shown later in this chapter.

45. The large intestine.—From the small intestine the undigested matter passes into the large intestine. Little, if any, digestive fluid is produced here, but a small amount of digestion may go on, owing to the digestive enzymes carried in from the small intestine and to the action of bacteria. From the large intestine are absorbed any soluble products, nutritive or otherwise. The bacteria may not only attack cellulose in the large intestine but also may cause the putrefaction of undigested protein, in which action foul-smelling substances are formed that are poisonous if

absorbed in large quantities. If the large intestine is not functioning properly and the contents remain an undue time, excessive putrefaction may take place, injuring the animal thru the absorption of the poisonous products formed.

46. Special provision for the horse.—The horse, tho eating coarse food like the ox, has a small stomach and no paunch for specially preparing such food for digestion. In partial compensation, the caecum and large colon, parts of the large intestine, are greatly enlarged, as has been previously pointed out. (35) The incompletely digested matter from the small intestine, together with the enzymes mixed with it, pass into the caecum. Here the enzyme action continues, and the cellulose of the feed is also attacked and digested by bacteria, as in the paunch of ruminants. Due to this, the horse is able to digest such feeds as hay and straw quite thoroly, tho less completely than do cattle and sheep. The caecum of other farm animals is relatively small and unimportant in digestion.

47. Digestion of fat.—Since the steps by which the food is prepared thru digestion for final use by the body are so numerous and complicated, it is well now to review the subject, dealing with the nutrients and what occurs with them, rather than considering the organs and solvents employed.

As has been stated, the fats of foods, no matter how finely divided, cannot directly enter the circulation, but must be changed in the following manner: One of the enzymes produced by the pancreas is the fat-splitting lipase, which breaks some of the fats in the food into glycerin and fatty acids. The bile is largely made up of alkaline salts, and with these the fatty acids react and form soaps. These soaps in turn form an emulsion with the unchanged fats, the emulsified fats presenting a large surface on which the lipase may act. Thus, it is believed that the fat which is finally absorbed is split into glycerin and fatty acids, the latter and the alkalies of the bile forming soaps. These soaps and the glycerin are absorbed by the intestinal wall, in the cells of which they are reunited into fats. Some authorities believe, however, that a part of the fatty acids and glycerin formed by the splitting of neutral fats by lipase may be absorbed as such, without being first changed to soaps.

48. Carbohydrate digestion.—The digestion of either starch or sugars (other than those of glucose-like form) consists in converting them into glucose or glucose-like sugars, which are the only forms of carbohydrates that can be used in the body. Since these carbohydrates constitute a large portion of the food of animals, Nature provides for their digestion in several parts of the alimentary tract. Carbohydrate digestion begins with the action of the ptyalin of the saliva, which splits starch into maltose. Ptyalin action continues in the first portion of the stomach, but ceases in the latter part of that organ. Nearly all the carbohydrates are carried on from the stomach into the small intestine, which is the principal organ concerned in their final digestion. Here the starches which have escaped digestion in the mouth and stomach are

acted upon by amylase, and the compound cane-, malt-, and milk-sugars are converted by the invertases into simple glucose-like sugars.

Thus when a human eats bread, or an animal consumes hay or corn, the starch in the food must all be changed to glucose before it can enter the body proper. Similarly the compound sugars in the food are converted almost completely into simple glucose-like sugars before they are absorbed, tho insignificant amounts of the compound sugars may possibly be absorbed unchanged from the digestive organs. If any unchanged cane sugar or milk sugar is absorbed into the blood from the intestines, apparently neither can be used by the body, but it is excreted without change in the urine.

In the digestive tract no enzyme has been found which acts on cellulose or on the pentosans. However, bacteria attack these substances, especially in the paunch of ruminants and the caecum of the horse. Among the products of such bacterial decomposition are organic compounds, such as acetic acid and lactic acid, besides gases—marsh gas, carbon dioxid, and hydrogen. While the gases are of no value to the animal, there is little doubt that the organic acids are absorbed from the digestive tract and serve as nutrients, because cattle, sheep, or goats can subsist for long periods on coarse straw, which consists largely of cellulose and pentosans. Some digestion of cellulose may possibly be brought about by enzymes contained in the food itself. When artificially digested with strong acid, cellulose is converted into a gummy product and finally into glucose or other simple sugars.

49. Protein digestion.—In the process of digestion the protein compounds in the food are attacked first by pepsin in the stomach, and later by trypsin and erepsin in the small intestine. The action of these enzymes is to cleave the very complex protein molecules into simpler ones, during which process the split molecules take up water and become soluble.

The pepsin of the gastric juice changes protein in the food into soluble proteoses and peptones. This action may readily be demonstrated by the following experiment: If a fragment of the white part of a hard-boiled egg, which is a protein substance, is placed in a dish with dilute hydrochloric acid, a little pepsin added, and the whole kept at body temperature, in a short time the edges of the opaque egg mass will become swollen and transparent, the change gradually extending thru the whole fragment. After a time the mass will have entirely disappeared, and in its stead there will remain a clear solution. If this solution is evaporated to dryness there will be left a yellowish, transparent mass resembling the dried white of an unboiled egg. This dry digested material, which is a mixture of proteoses and peptones, is soluble in water the same as the white of egg; but if dissolved in water it will not solidify on heating, as does ordinary white of egg. This shows that the substance has been changed to something other than the protein, which coagulates or solidifies on heating.

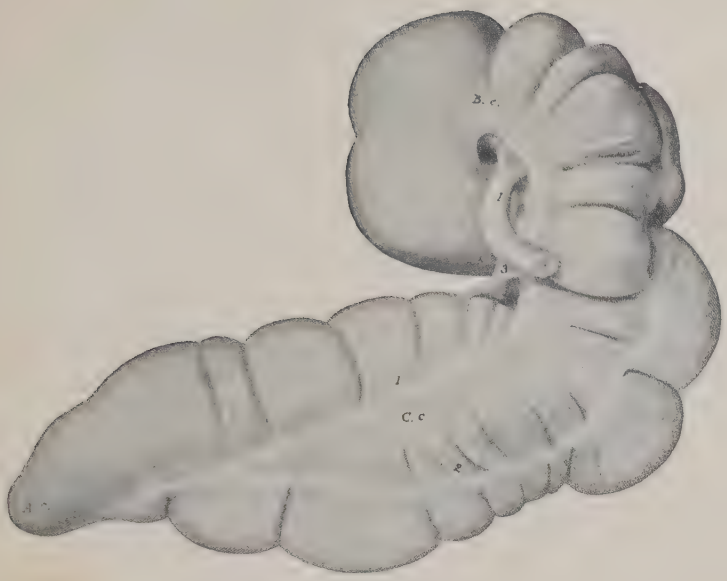
These proteoses and peptones have resulted from the cleavage or splitting of the very complex egg protein into simpler molecules. Upon such cleavage these molecules have taken up chemically a large amount of water and become soluble. When a piece of lean meat or hard-boiled egg is taken into the human stomach, the pepsin, acting in the presence of hydrochloric acid, gradually dissolves such meat or egg in a similar manner, changing it to soluble peptones and proteoses. If it escapes solution in the stomach, it is usually dissolved later in the small intestine.

The soluble proteoses and peptones are not yet in suitable form for use in the body of the animal, and so are not absorbed, but are retained in the small intestine until they have been acted upon further by trypsin and erepsin. Trypsin, an enzyme of the pancreatic juice, not only attacks protein directly and converts it into proteoses and peptones, as does pepsin in the stomach, but can also attack the peptones and proteoses and cleave them further. Erepsin, an enzyme of the intestinal secretion, also acts on proteoses and peptones and splits them into simpler compounds. By the action of these last two enzymes the proteoses and peptones are finally cleaved into amino acids, which, as we have learned, are the "building stones" from which proteins are formed.

The amino acids are soluble in the juices of the small intestine and are ready for transference thru the intestinal walls into the blood to be carried to various parts of the body. These amino acids are still relatively complex in structure, but are much simpler than the proteoses and peptones. They form the great primary nitrogenous building material out of which the protein tissues of the animal body are built. So far as known, protein compounds taken as food cannot be broken apart further than into amino acids and remain useful in body building.

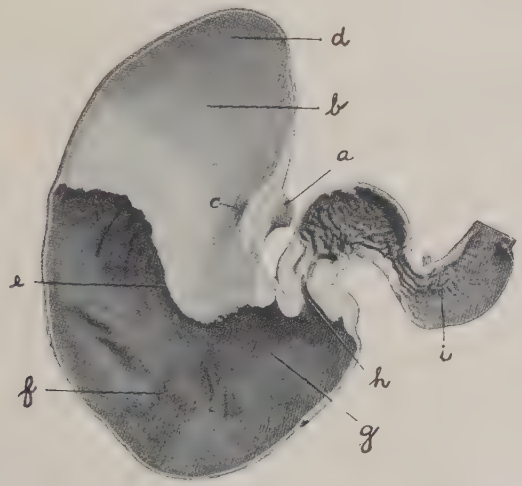
50. Tissue building.—The process of protein digestion is the breaking down of complex nitrogenous bodies into simpler ones. A good picture of what takes place can be had by likening the protein molecule to a house being taken down by a builder in order that he may construct another from the materials. An animal eating protein compounds cannot use the protein molecules in the form in which the plant has built them up into its own substance, but must first take them apart to a greater or less extent, and from the parts reconstruct another kind of protein molecule suitable for its own use. In others words, its protein molecules must have a different architecture from those of the plants which serve as its food. The proteoses and peptones may be likened to the roof and walls of the house. These walls and the roof can be broken down into bricks and tiles, which are represented by the amino acids; and from these the animal, beginning anew, can construct new proteins of the specific architecture its body may require.

51. Bacteria.—In the stomach bacteria find unfavorable conditions for growth, because of the free acid of the gastric juice, and in the small intestine the presence of bile rapidly causes the death of bacteria. Consequently bacteria play little or no part in digestion in either the



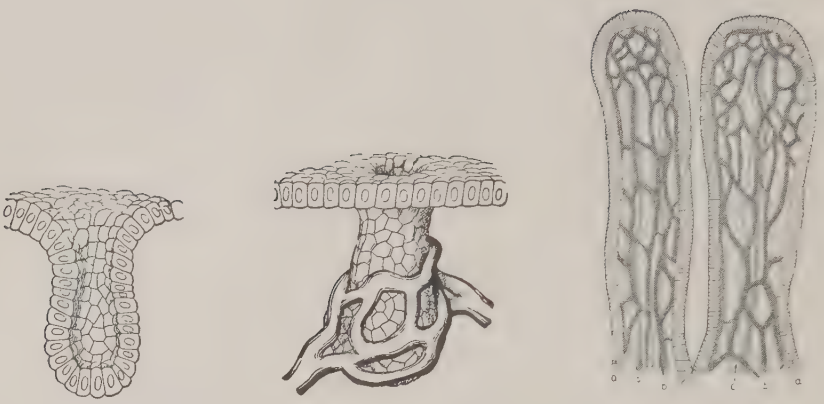
CAECUM OF HORSE

The entrance of the small intestine is designated (I). The opening of the cæcum into the large intestine is hidden from view. (From Sisson, "Anatomy of the Domestic Animals.")



LONGITUDINAL SECTION OF STOMACH OF THE HORSE

A, Œsophagus, or gullet; b, œsophageal region of stomach, in which no gastric juice is secreted; c, entrance of gullet; d, left extremity of stomach; e, boundary between œsophageal region and portion of stomach secreting gastric juice; f, g, fundus gland region and pyloric gland region, in which gastric juice is secreted; h, pylorus, or ring of muscles closing the stomach; i, entrance of pancreatic and bile ducts. (From Sisson, "Anatomy of the Domestic Animals.")



LEFT AND CENTER—THE PRINCIPLE OF THE STRUCTURE OF GLANDS

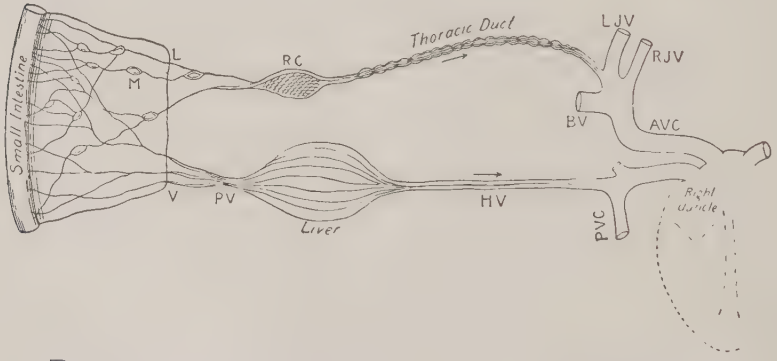
Left.—A vertical section of a simple microscopic gland. The cells are seen to surround a recess, into which they discharge their secretion.

Center.—The same structure with the encircling blood-vessels. (From Stiles, "Nutritional Physiology.")

RIGHT—VILLI OF THE SMALL INTESTINE

A, lining cells of intestine; b, net work of capillaries; c, lacteals.

For the sake of simplicity the muscle fibers in the villi are not shown in this diagram. (After Cadiat.)



DIAGRAMMATIC REPRESENTATION OF THE TWO PATHS OF ABSORPTION

V, Veins from the small intestine, which unite to form the portal vein, P. V.; H. V., hepatic vein, passing from the liver to the posterior vena cava, P. V. C.; L, lacteals, which join and drain into the mesenteric lymph glands, M, and then pass to the lymph receptacle (receptaculum chyli), R. C.; L. J. V., left jugular vein; R. J. V., right jugular vein; B. V., brachial vein; A. V. C., anterior vena cava. (From Hadley, "Principles of Veterinary Science.")

acid stomach or the alkaline small intestine. They do act, however, on the cellulose and the pentosans, and in some cases on soluble carbohydrates, in the first three stomachs of ruminants and in the caecum of the horse. In the large intestine there develops a profuse bacterial growth of various forms which thrive in the absence of air. The presence of more or less undigested food, together with moisture, warmth, and the faint alkaline reaction furnish ideal conditions for bacterial growth. Some cellulose is decomposed by the bacteria, with the liberation of carbon dioxid, marsh gas, and hydrogen. Sulfureted hydrogen is also produced thru putrefaction of protein substances. Some nitrogen is found, but this has its source in the air taken in with the food. Much of the gas is doubtless absorbed into the circulation and eliminated from the lungs. Products other than gas, which are mostly toxic or poisonous to the animal, result in small quantity from bacterial growth in the large intestine. To these substances the odor of the feces is largely due. If the bowels do not function properly, the contents may remain for an undue length of time, in which case excessive putrefaction may cause the animal to suffer from poisoning, due to the absorption of the poisonous substances.

52. Feces.—As the intestinal contents pass thru the latter part of the large intestine, some of the water is absorbed and a more or less solid residue accumulates in the rectum. This is voided as the feces. With farm animals these are chiefly undigested food that has never really been within the body proper. This undigested food is mostly cellulose, or crude fiber, which has escaped bacterial action. Also a portion of the other nutrients usually escapes digestion. This may be due to insufficient chewing of such food as seeds, or because some nutrients are protected from the digestive juices thru being enclosed in resistant cell walls of cellulose. In addition to undigested food the feces also contain residues from the bile and other digestive fluids, waste mineral matter, worn-out cells from the intestinal lining, mucus, and bacteria. They may also contain such foreign matter as dirt consumed along with the food.

53. Amid digestion.—Those nitrogenous compounds of plants which are classified as "amids" are, as before stated, simpler nitrogenous compounds than the proteins. They are either on their way to be built into proteins, or result from a partial breaking down or cleavage of proteins, such as occurs in the plant for the purposes of transportation.

In many instances the amids are similar in character to some of the intermediate products of digestion in the animal body. Their digestion is therefore doubtless similar to that of the proteins.

54. Mineral matter.—Tho the digestion of the mineral matter of foods has not been extensively investigated, it is known that the mineral matter is dissolved to a greater or less extent by the hydrochloric acid of the gastric juice, and is absorbed principally from the small intestine. Sulfur and phosphorus, which occur in feeds largely as a part of pro-

teins, are digested and absorbed in the changes which these nutrients undergo.

55. The work of the digestive glands.—The brilliant studies of the Russian physiologist, Pawlow,[3] and his associates, followed by others along similar lines, have thrown much light upon the subjects of digestion, appetite, and palatability. In order to study the processes of digestion, operations such as the following were performed on many dogs: (1) The ducts, or tubes, which deliver the saliva into the mouth were cut, turned outward, and healed into the cut edges of the skin, so that when saliva was secreted it poured out thru the opening and could be caught in glass tubes attached to the dog's head. (2) The gullet, which carries food from the mouth to the stomach, was cut across, led outward, and healed in the skin at the throat, so that when food was swallowed it would pass out at the severed end and fall back into the dish out of which he was feeding. Food so eaten was called a "false meal." In many cases a dog with a gullet thus severed would chew and swallow the "false meal" again and again with apparent satisfaction. (3) An opening was made thru the side of a dog and into his stomach. On the healing of the stomach wall with the cut in the skin, the investigator was enabled to pass food directly into the stomach and study the processes of digestion occurring within that organ. (4) A portion of the stomach was constricted and made into a small separate chamber which likewise opened out thru the side of the dog. Here the flow of juices could be studied independent of admixture with food placed in the other portion of the stomach. (5) The small intestine was drawn to the side of the dog, and an opening made in it the same as in the stomach. (6) The pancreatic duct was cut and led outward, so that its secretion could likewise be studied. The animals usually yielded readily to the operations and lived comfortable lives, so that the results were normal.

It was found that the sight, smell, or taste of food not only started the flow of saliva in the mouth, but the gastric juice also began to pour from the walls of the stomach in about five minutes, even when there was no food in that organ. The gastric secretions which are brought forth by the sight, taste, or smell of food were designated by Pawlow as "psychic secretions." For example, when a dog was given a false meal, and the swallowed food fell out of the fistula, or opening, in the throat and back into the dish out of which the dog was eating, the stomach would nevertheless pour forth its fluids (psychic secretions), as tho the food had reached it. The more eagerly the dog ate his false meal the greater was the amount of gastric juice, and the richer it was in both acid and pepsin. The gastric secretions were strongest and most abundant with that food which was liked best, and food given in small portions called forth stronger juices than when the whole ration was given at one time.

These psychic secretions do not last long enough to explain the long continued flow of gastric juice when a normal meal is eaten.

[3] The Work of the Digestive Glands.

In studying other causes which might produce the secretion, it was found that no flow could be started by such mechanical stimulation as passing a feather or a glass rod over the mucous membrane of the stomach. Water caused a moderate flow of gastric juice, but when fat, egg albumin, starch, or sugar was introduced with water no greater flow resulted than with water alone. However, the juice of meat, which contains simple nitrogenous compounds, called forth a marked flow. This explains the continuance of the secretion after the psychic secretion ceases. The gastric juice secreted as a result of the mental stimulus digests some of the protein of the food, forming soluble nitrogenous compounds, which in turn stimulate the glands to further secretion.

The saliva secreted was thin and watery when sand or dry, powdered biscuit was placed in the dog's mouth, and much more concentrated when stones were introduced, which the dog could swallow without the aid of a large amount of saliva. The amount of saliva and gastric juice also depended on the nature of the food fed. Pawlow's work indicated that the enzyme content of the digestive juices depended on the kind of food, the glands being guided by a form of instinct, so that, for example, the pancreatic juice would contain more trypsin when meat was fed than when starch was supplied. However fascinating this idea is, after numerous more recent investigations the consensus of opinion is now against such an adaptation of the digestive juices to the nature of the food.

It is indeed fortunate that the character of the digestive juices of an animal is not changed with variations in the food consumed. Between meal times the secretory cells are elaborating the enzymes which are to be contained in the secretions that will be poured forth to digest the next meal. If the cells formed only enzymes suited to the digestion of the previous meal and the animal then consumed food of a different kind at the following meal, the juices might be unsuited to its digestion. It is therefore wise that no matter what food the animal consumes, the digestive glands pour forth the enzymes needed for the digestion of all the various nutrients.

56. Palatability.—The palatability of feeds is a factor of no small importance in the feeding of stock. The experiments which have just been reviewed show clearly that the mere sight or smell of well-liked food will cause some flow of gastric juice. It is reasonable to believe, therefore, that well-liked feeds are digested better than others which may be equally nutritious but less palatable.

Familiarity and habit are important factors concerned with the palatability of feeds. When corn silage is first placed before cows, not infrequently, after sniffing it, they will let it alone for a time. They then usually begin nibbling at it, and later eat it with great relish. In such cases food that at first seems unpalatable finally becomes palatable. In his early experience the senior author was feeding two lots of fattening steers, one on shelled corn and wheat bran, the other on ground corn and wheat bran. After some weeks of successful feeding, the

rations for the two lots were reversed. The steers changed from ground corn to whole corn showed a strong dislike for the new ration, eating so little at first that they shrank materially in weight. From this the general conclusion might have been drawn that shelled corn is less palatable than ground corn for fattening steers. But the steers given ground corn in place of shelled corn were equally dissatisfied. This shows that custom and habit may be important factors in making a certain feed palatable or unpalatable to any animal.

While palatability may increase the digestibility and consequently the nutritive value of a given feed, it does not follow that feeds are nutritious or beneficial merely because they are palatable. Humans and animals often show fondness for kinds of food that are indigestible or worse. Even poisonous substances may be palatable. For example, while cottonseed meal is an excellent feed for most classes of stock when fed in proper amounts, it is strikingly poisonous to pigs, even tho it is palatable to them. (249) On the other hand, food which the human or animal does not relish or even dislikes may have high nutritive value provided their repugnance for it is overcome. Often by mixing a limited amount of poorly-liked feed with some palatable feed, the animals may be induced to eat the entire mixture readily.

Tho the question of palatability is more or less complicated, every practical stockman realizes the importance of providing for his animals feed which is palatable. This may be accomplished largely thru the feeding of balanced rations made from feeds suitable for the given class of animals, and in always avoiding sudden and violent changes in the character of the ration and in the manner of feeding. It is especially important to supply palatable feed to animals which are being fed for high production—whether of meat, milk, or work. For animals which are merely being maintained, such as idle horses, or else steers being carried over winter to be fattened on grass the next season, it is commonly most economical to use largely such coarse and less palatable feeds as straw and stover.

III. Metabolism

In the preceding division we learned how digestion prepares the nutrients of feeding stuffs for the nourishment of the animal body. In what follows there is briefly set forth how the digested materials are brought into the body proper and what becomes of them. Chemists and physiologists, working together with skill and great patience, have been able quite fully to set forth and explain the processes of digestion. When the nutrients leave the alimentary tract and enter the body, the difficulties of following them and learning what becomes of them are much greater. Many of the changes that occur in the body have been revealed by persevering scientists, but concerning others, only little of a definite nature can yet be told.

57. Metabolism.—The changes which the digested and absorbed nutrients undergo within the body in their use for various purposes are termed *metabolism.* As is discussed in detail in the following chapters, the nutrients may be built up into the living matter of the body, or they may be broken down in the production of heat and work. Constructive metabolism, or the building-up processes, is termed *anabolism,* while the breaking-down and wasting processes are called *catabolism.*

58. The circulative canals of the body.—The body of the animal is made up of innumerable cells, which, grouped and modified in myriads

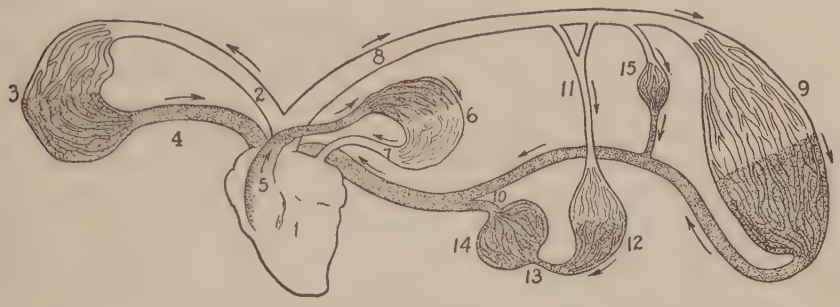


DIAGRAM OF THE CIRCULATION OF THE BLOOD

1. The heart; 2, artery carrying blood to the head and fore limbs; 3, circulation thru the upper portion of the body; 4, vein carrying blood from upper part of body back to the heart; 5, artery carrying venous blood to lungs; 6, circulation thru lungs; 7, vein carrying arterial blood back to heart; 8, artery carrying blood to lower portion of body; 9, circulation thru rear extremities; 10, vein carrying blood to heart from rear extremities; 11, artery carrying blood to intestines; 12, circulation thru intestinal capillaries; 13, portal vein carrying blood to liver; 14, circulation thru liver; 15, circulation thru kidneys. (From Smith, "Manual of Veterinary Physiology.")

of ways, ultimately form all its organs and parts. Everywhere among the cells are minute spaces called *lymph spaces,* which are connected with the *lymphatics,* a set of vessels which permeate the various tissues of the body. In some respects the lymphatics resemble the veins, but they are thinner and more transparent and drain in only one direction—toward the heart. Within these vessels is a clear fluid called *lymph.* These vessels unite with one another, forming a network in many places. Here and there a trunk subdivides into five or six smaller vessels, and the latter enter a nodule-like body called a *lymphatic gland.* From this gland come several small vessels, which, after a short space, again unite to form a trunk. Gradually these trunks unite, forming larger trunks until a large duct and another smaller one are formed which enter veins in the neck.

The arteries and veins form the other set of canals. These permeate every portion of the body, the former carrying the blood away from the heart, and the latter carrying it to the heart. At the extremities of the arteries are still more minute tubes, called *capillaries,* which connect them

with the veins. If one extends his arms in front of him with his finger tips touching, his body will represent the heart, while one arm will represent an artery carrying blood from the heart, and the other a vein conveying blood to the heart. The touching fingers will correspond to the capillaries connecting the arteries with the veins, and the space all about the fingers will represent the surrounding body tissues. In general, neither the veins nor the arteries allow any substance within them to escape thru their walls proper. It is thru the capillaries that the nutritive matter carried by the blood finds its way into the body tissues for their nourishment, and thru the capillaries and the lymphatics, in turn, the waste of the body drains back into the blood circulation.

The digested nutrients are absorbed into the circulation of the body chiefly by the mucous membrane of the small intestine. In order to provide a larger surface so that the nutrients may be more readily and completely absorbed, this mucous membrane has innumerable cone-like projections, called *villi.* These villi, which give the mucous membrane a velvety appearance, project toward the center of the intestinal tube and thus come into intimate contact with the fluid contents. Within each villus are *lacteals,* or drainage tubes of the lymphatic system, and capillaries of the blood system. The veins from the intestine unite and form the portal vein, which carries the absorbed nutrients to the liver and then on to the heart.

59. Absorption of fat.—As has been previously explained, thru the action of the lipase in the pancreatic juice and the alkalies in the bile, practically all the fat in the food is changed into soaps and glycerin. The bile aids in dissolving these soaps, so they are more readily absorbed by the villi of the small intestine. In the villi the soaps and the glycerin are reconverted back into fat, which then enters the lacteals in the villi, forming with the lymph a milky substance called *chyle.* This is carried in the lymphatics and poured into a vein near the shoulder, thus entering the blood circulation.

60. Absorption of carbohydrates; formation of glycogen.—Thru the action of the ptyalin of the saliva, the amylase of the pancreatic juice, and the invertases of the intestinal juice, a very complete digestion of the starch and the compound sugars in the food occurs, in which they are all converted to glucose or other simple sugars. These are absorbed chiefly by the villi of the small intestine, passing into the capillaries and then entering the veins. When the sugars reach the liver, they are for the most part withdrawn from the blood and temporarily stored in this organ as *glycogen,* a carbohydrate which is closely related to starch and, having the same percentage composition, is sometimes called animal starch. Normally from 1.5 to 4.0 per ct. of the weight of the liver consists of glycogen. The glycogen stored in the liver is gradually changed back into glucose, and then doled out to the system as required, the amount of glucose in the blood being kept at about 1 part in 1,000. The property of converting glucose into glycogen is not

possessed by the liver alone, but by the tissues of the body generally, especially the muscles. When work is being done the glycogen in the muscles is first drawn upon to furnish glucose, and after this store has been exhausted, the glycogen in the liver furnishes the needed glucose.

61. Absorption of proteins.—We have previously learned how the protein in the food is digested by pepsin, trypsin, and erepsin, and split into amino acids, the "building stones" of the proteins. These amino acids are absorbed by the villi of the small intestine. It was formerly believed that they were joined together while still within the intestinal walls, forming the complex proteins of the blood called *serum albumin* and *serum globulin*. Thru refinement of experimental methods, Van Slyke,[4] and Folin and Denis[5] have been able to prove that the amino acids are not necessarily thus built into blood proteins in the intestinal wall, but that they may pass into the blood stream without being united. They are then carried into the general circulation, and from the blood stream each of the various tissues of the body—muscles, organs, etc.—absorbs a certain amount of the amino acids for growth, or the repair of the daily waste of protein matter.

Mineral matter is absorbed by the villi of the small intestine, and water is taken up all along the digestive tract, from the stomach to the large intestine.

62. Distribution of absorbed nutrients.—We have seen that the digested fats, which are to nourish the body, are poured into the blood current by way of the lymphatics, while the sugars, the amino acids, and the mineral matter enter the blood directly thru the capillaries and veins. The various nutrients are carried in the blood thru the circulation to the capillaries. These are so constructed that, when the blood finally reaches them, the nutritive substances it carries pass thru their walls and are mingled with lymph that bathes the myriad body cells. In this manner all the nutrients, having been especially prepared and transported, are available for the nourishment of every portion of the body.

63. Use of the absorbed nutrients.—The absorbed nutrients, thus transferred to all the tissues of the body, may be oxidized, or burned, to warm the animal, or to produce energy to carry on the vital processes and to perform work, as shown in the following chapters. In case more nutrients are supplied than are required for these purposes, the excess may be transformed into body tissue proper, as shown in Chapter V. The sugars may be converted into fats and stored as body fat, as may also the fats derived directly from the food fats. The amino acids may be built up into body protein or, if not needed for this purpose, a portion of their carbon, hydrogen, and oxygen may be converted into fat, while the nitrogen is excreted, chiefly in the form of urea. The highest use of the proteins, however, is the formation of nitrogenous tissues—the muscles, brain, nerves, skin, hair, and various organs of the body.

[4]Jour. Biol. Chem., 12, 1912, 399-410; 16, 1913, 187-233.
[5]Jour. Biol. Chem., 11, 1912, 87-95; 12, 1912, 141-162.

It has been previously pointed out that most of the changes in the digestion of food are produced by enzymes. (37) Scientists now believe that most other body processes, both the building up and the tearing down processes, are brought about by enzyme action.

64. Disposal of body waste.—In breaking up the food nutrients within the body proper for the production of heat, and in the changes which occur in building them into body tissues, carbon dioxid is evolved. Most of this escapes into the capillaries and is carried in the blood by the veins to the lungs, where it is eliminated in breathing, a portion, however, escaping by way of the skin. Some of the marsh gas produced by fermentations in the stomach of herbivora is absorbed into the blood and thrown out by the lungs.

Nearly all of the nitrogenous waste, representing the breaking down of protein material in the body, is excreted in the urine thru the kidneys, tho a trace is given off in the sweat and a more appreciable amount in the feces. In mammals this waste takes the form principally of urea. In calculating the total amount broken down in the body it is customary to determine the total nitrogen in the urine and multiply this by 6.25. This gives the amount of protein broken down, since it is assumed that, on the average, nitrogen forms 16 per ct. of the total weight of proteins. (17)

A great variety of other end-products of metabolism are likewise eliminated by the kidneys thru the urine. Most of the mineral matter, such as common salt, is excreted in large part or principally in the urine. However, calcium, magnesium, iron, and phosphorus are voided chiefly in the feces. Small amounts of most of the substances eliminated in the urine are also excreted by the skin thru the sweat glands.

65. Summary.—In Chapter I we learned how the various inorganic compounds taken by plants from earth, air, and water are built into organic plant compounds, and how in such building the energy of the sun becomes latent, or hidden, in the substance of the plant. In this chapter we have learned how the animal, feeding on plants, separates the useful from the waste by mastication and digestion, and how the digested nutrients, after undergoing more or less change, are conveyed from the digestive tract to the body tissues and used for building the body, for warming it, or in performing work. All the energy manifested by living animals and the heat evolved in their bodies represent the energy of the sun originally stored in food substances by plants. With the breaking down of the nutrients in the bodies of animals, and in the decay of the animal substance itself, the organic matter loses the condition of life and falls back to the inorganic condition, once more becoming a part of the earth, air, and water as inert matter. After this degradation it is again gathered up by the plants and once more starts on the upward path. Such is the eternal round of Nature, in which plants, animals, the energy of the sun, and the mysterious guiding principle of life all play their parts.

CHAPTER III

MEASURING THE USEFULNESS OF FEEDS

I. Digestibility of Feeds

In determining the relative usefulness of different feeding stuffs to the animal, it is necessary to find a means of measuring the amount of nutrients which each actually furnishes. The most simple method is to determine the digestibility of the various nutrients; i. e., the percentage of each class of nutrients in the feed which is digested by the animal. The digestible matter is obviously the only portion of the feed which is of use, since the remainder passes out in the feces without ever having really entered the body.

66. A digestion trial.—In studying the digestibility of a given feed the chemist first determines by analysis the percentage of each nutrient it contains. An animal is then given the feed to be tested for a preliminary period of a few days in order that all residues of former feed may pass from the digestive tract. Weighed quantities of the feed are then given to the animal, and the feces voided during a stated period are collected and weighed, and samples are analyzed. The amount of each nutrient which is digested is found by subtracting the amount which is excreted in the feces from the total amount in the feed. The amount voided in the urine is not deducted in addition, due to the fact that the compounds in the urine are not undigested food, but are waste products which have come from the breaking down within the body proper of substances which have at some previous time been digested and absorbed from the digestive tract.

To show the manner in which the digestibility of a feed is determined, the following results are given from an actual digestion trial conducted by Armsby at the Pennsylvania Station.[1] To find the digestibility of red clover hay he fed a steer 5,198.2 grams (about 11.5 lbs.) of clover hay daily during a 10-day trial, after the steer had already been fed the same ration for several days previously. By analyzing the feed, it was found that the hay fed each day contained the amount of nutrients shown in the table on the next page. The feces were collected by means of a rubber duct and a harness which is used in such trials. On analysis, they were found to contain the amounts indicated of undigested dry matter, crude protein, fiber, nitrogen-free extract, and fat.

The table shows that the hay fed daily contained 4,459.0 grams of dry matter. Of this amount there was excreted in the feces 1,822.3 grams, leaving 2,636.7 grams, or 59.1 per ct., as the digested part of the

[1] Penn. Rpt. 1904-05, Part II, pp. 124-126.

dry matter. Similarly, it was found that of the 631.2 grams of crude protein in the feed, 270.0 appeared in the feces, and 361.2 grams, or 57.2 per ct., was digested. In a like manner the percentages of the other nutrients that were digested were determined.

Digestion trial with a steer fed clover; average for 1 day

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Grams	Grams	Grams	Grams	Grams
Fed 5,198.2 grams hay, containing	4,459.0	631.2	1,510.4	1,902.8	129.2
Excreted 9,169.8 grams feces, containing	1,822.3	270.0	773.8	580.4	44.8
Digested	2,636.7	361.2	736.6	1,322.4	84.4
Per cent digested	59.1	57.2	48.8	69.4	65.3

67. Digestibility determined by difference.—Some feeds cannot be fed alone, as was done in this trial. For instance, horses and ruminants are not fed only concentrates without hay or other roughage. Again, while pigs may be fed on grain alone, such feeds as tankage and linseed meal are too rich in protein to be fed thus. The digestibility of these feeds must therefore be found by difference, instead of directly.

This method of determining the digestibility of a feed is illustrated in the following: To find the digestibility of ground corn, after Armsby had carried on the digestion trial with red clover hay which has been previously described, he then fed the same steer a ration of 3,700 grams clover hay and 4,000 grams ground corn during another digestion trial. The hay in this ration contained 3,186.4 grams dry matter and the corn, 3,450.8 grams dry matter, making a total of 6,637.2 grams. Of this amount there was voided in the feces 1,577.4 grams, leaving 5,059.8 grams as the total digested from both hay and corn. In the previous trial it was found as the average of 2 periods that 59.4 per ct. of the dry matter in the clover hay was digestible. Taking 59.4 per ct. of 3,186.4 grams, the total amount of dry matter in the clover hay fed, gives 1,892.7 grams, which was the probable amount of dry matter that was digested from the hay. Subtracting 1,892.7 grams from 5,059.8 grams, there was left 3,167.1 grams, which was taken as the amount of dry matter digested from the 3,450.8 grams of total dry matter in the corn which was fed. This therefore gave 91.8 per ct. as the percentage of the dry matter which was digested. In a similar manner there were determined the percentages which were digested of the different nutrients in the corn.

68. Coefficients of digestibility.—The percentage of each nutrient digested in a feeding stuff is termed the *coefficient of digestibility,* or *digestion coefficient,* for that nutrient in the feed.

As is explained later in this chapter, due to the fact that cattle and sheep are ruminants, they digest feeds high in fiber more completely

than do horses and swine. (85) In spite of this difference, the coefficients of digestibility obtained with ruminants are commonly used in computing rations for horses and swine as well, for but few digestion trials have been carried on with the latter animals. However, no error of consequence is involved in this, for the recommendations in modern feeding standards are designed to meet these conditions.

Individual animals of the same species vary somewhat in their ability to digest the same feeds. For this reason, it is essential, when computing the digestible nutrients in feeds as a basis for balancing rations for live stock, to use average coefficients of digestibility, based on all representative digestion trials which have been conducted. The authors have therefore compiled and averaged the coefficients for the various feeding stuffs, as determined in the many trials by the experiment stations. These average coefficients of digestibility are presented in Appendix Table II. In the case of feeds for which American data are not available, coefficients from European sources have been included. From this extensive table the following examples are taken to show the digestibility of typical feeds:

Coefficients of digestibility of typical feeding stuffs, from Appendix Table II

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Concentrates						
Dent corn	12	90	74	57	94	93
Oats	17	70	78	35	81	87
Wheat, ground	4	87	74	59	93	72
Wheat bran	20	65	78	31	72	68
Flax seed	7	77	91	60	55	86
Linseed meal, old process	3	79	89	57	78	89
Roughages						
Timothy hay	58	55	48	50	62	50
Red clover hay	25	59	59	54	66	57
Oat straw	18	54	28	60	51	39
Kentucky bluegrass, green	7	56	57	66	61	52
Corn silage	27	66	51	65	71	82
Mangels	22	87	70	37	95	..

The table shows that for dent corn 90 per ct. of the total dry matter, 74 per ct. of the crude protein, 57 per ct. of the fiber, 94 per ct. of the nitrogen-free extract, and 93 per ct. of the fat are digestible. Feeds which contain little fiber, such as corn and wheat, show high digestibility, because their nutrients are not protected from the action of the digestive juices by thick cell walls of cellulose, or fiber. Owing to their larger fiber content, oats and wheat bran are less digestible than corn or wheat. As

a class the roughages are high in fiber, and therefore much less digestible than the concentrates. This will be noted on comparing the digestion coefficients for timothy hay and oat straw with those for corn and wheat. The dry matter of mangels is as well digested as that of wheat, again showing that roots are more like concentrates than roughages.

69. Digestible nutrients in feeding stuffs.—To determine the digestible nutrients in any feeding stuff the total amount of each nutrient in 100 lbs. of the feed is multiplied by the digestion coefficient for that nutrient. For example, 100 lbs. of dent corn contains 10.1 lbs. of crude protein (Appendix Table I), of which 74 per ct. is digestible, as shown by the preceding table. Accordingly, there are 7.5 lbs. of digestible protein in 100 lbs. of this grain. By this method the data contained in the extensive Table III of the Appendix have been computed. The following examples are here taken from this table for illustration and study.

Digestible nutrients in 100 lbs. of typical feeding stuffs, from Appendix Table III

Feeding stuff	Total dry matter	Digestible nutrients				Nutritive ratio
		Crude protein	Carbohydrates	Fat	Total (inc. fat x 2.25)	
Concentrates	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Dent corn	89.5	7.5	67.8	4.6	85.7	1:10.4
Oats	90.8	9.7	52.1	3.8	70.4	1: 6.3
Wheat	89.8	9.2	67.5	1.5	80.1	1: 7.7
Wheat bran	89.9	12.5	41.6	3.0	60.9	1: 3.9
Flax seed	90.8	20.6	17.0	29.0	102.8*	1: 4.0
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1: 1.6
Roughages						
Timothy hay	88.4	3.0	42.8	1.2	48.5	1:15.2
Red clover hay	87.1	7.6	39.3	1.8	51.0	1: 5.7
Oat straw	88.5	1.0	42.6	0.9	45.6	1:44.6
Kentucky bluegrass, green	31.6	2.3	14.8	0.6	18.5	1: 7.0
Corn silage, recent analyses	26.3	1.1	15.0	0.7	17.7	1:15.1
Mangels	9.4	1.0	6.1	0.1	7.3	1: 6.3

*The high value for flax seed is due to the fact that its 29.0 lbs. of digestible fat equals 65 lbs. of digestible carbohydrates (29.0x2.25=65.2).

In Appendix Tables I and II the fiber and nitrogen-free extract are given in separate columns, for, tho of the same chemical composition, these components usually differ widely in digestibility. In preparing the tables showing the digestible nutrients in feeding stuffs, the digestible fiber and digestible nitrogen-free extract are determined separately and the results combined under the term *carbohydrates,* as is done in this table. The digestible carbohydrates in dent corn are computed as follows: According to Appendix Table I, 100 lbs. of dent corn contains 2.0 lbs. of fiber, 57 per ct. of which is digestible, as shown in Appendix

Table II. Likewise there are 70.9 lbs. of nitrogen-free extract, 94 per ct. of which is digestible. Multiplying in each case and adding the products, we have 67.8 lbs. as the "digestible carbohydrates."

It will be noted that the typical feeds presented in this table show wide differences in the amounts of different digestible nutrients they furnish. Corn and wheat are high in digestible carbohydrates and rather low in digestible protein, while wheat bran and linseed meal are high in digestible protein but low in digestible carbohydrates. Linseed meal contains more digestible protein and less than one-fourth as much digestible fat as the flax seed from which it comes. The roughages range lower in digestible nutrients than the concentrates. Oat straw is especially low in digestible protein, while immature and actively growing pasture grass will contain nearly as much digestible protein as wheat bran, if cut and dried to the same water content.

70. Nutritive ratio.—As protein serves special uses in the body, in discussions of feeding stuffs and rations the term nutritive ratio is used to show the proportion of digestible protein contained in comparison with the other nutrients.

The *nutritive ratio* of any feed is the proportion, or ratio, between the digestible crude protein and the combined digestible carbohydrates and fat. It should be noted especially that the nutritive ratio is based on the *digestible* and not the *total nutrients,* and furthermore that it is based on *digestible crude protein* and not *digestible protein.*

The nutritive ratio of a feed is computed in the following manner: The digestible fat in 100 lbs. of the given feed is multiplied by 2.25, because fat will produce 2.25 times as much heat on being burned in the body as do the carbohydrates. The product is then added to the digestible carbohydrates and the sum is divided by the amount of digestible crude protein, the quotient being the second factor of the ratio. The nutritive ratio of dent corn is computed as follows:

$$\frac{\text{Diges. fat } (4.6 \times \text{Heat equiv. } 2.25) + \text{Diges. carbohydrates } 67.8}{\text{Diges. crude protein } 7.5} = \text{Second factor of nutritive ratio } 10.4$$

Nutritive ratios are expressed with the colon, thus, 1:10.4. The nutritive ratio of dent corn is therefore 1 : 10.4 (read 1 to 10.4) ; i. e., for each pound of digestible crude protein in corn there are 10.4 lbs. of digestible carbohydrates or fat equivalent. A feed or ration having much crude protein in proportion to carbohydrates and fat combined is said to have a *narrow nutritive ratio;* if the reverse, it has a *wide nutritive ratio.* Oat straw has the extremely wide nutritive ratio of 1:44.6, because of its low content of digestible protein compared with the carbohydrates and fat; oats the medium one of 1:6.3; and protein-rich linseed meal the very narrow ratio of 1:1.6, the carbohydrates and fat being less than twice the crude protein.

When the total digestible nutrients (including fat $\times$ 2.25) in a feed or ration are given, as in Appendix Table III and this sample table, the nutritive ratio may be computed by simply subtracting the digestible crude protein from the total digestible nutrients, and dividing the remainder by the digestible crude protein. For example, the nutritive ratio of dent corn may be found thus: (85.7—7.5)÷7.5=10.4, second term of nutritive ratio.

71. Carbonaceous feeds; nitrogenous feeds.—The term *carbonaceous feed,* which has recently come into common use, is a convenient designation for a feeding stuff having a wide nutritive ratio. Similarly, the term *nitrogenous feed* designates a feeding stuff having a narrow nutritive ratio; i. e., one rich in protein.

72. Limitations of digestion trials.—The data secured in digestion trials concerning the digestibility of feeds form the general basis for the computation of balanced rations for all classes of live stock. Even the net energy values of feeds, which, as we shall see later, are theoretically more accurate measures of the relative values of different feeds than are the amounts of digestible nutrients, have been computed for the most part from tables of digestible nutrients, such as Appendix Table III of this volume. These values for digestible nutrients thus furnish for most feeds the most accurate information we have concerning the usefulness of each feed to farm animals. However, in studying tables of digestion coefficients and digestible nutrients it is well to bear in mind the following facts concerning the limitations in securing data of this sort:

In digestion trials it is commonly assumed that all matter appearing in the feces represents the part of the food which is actually indigestible. This is only approximately correct, for the feces always contain in addition some waste from the body itself, such as unabsorbed residues from the bile and other digestive juices, worn-out cells and mucus from the membranes lining the digestive tract, and waste mineral matter. The feces also include innumerable bacteria and their dead remains. In herbivora, such as cattle and horses, which eat much roughage, these products form but a small part of the feces, while in carnivora, such as dogs, they form a considerable portion. All these constituents of the feces are waste products. Therefore, while they do not represent undigested food, it is entirely correct from a practical standpoint to deduct them, along with the food which is actually undigested, in determining the digestible nutrients which are of use to an animal. These intestinal waste products which are excreted in the feces are a part of the cost of digesting the feed, as they represent the "wear and tear" of the digestive organs.[2]

In nutrition studies, when it is desired to determine how much of the protein of the feed has actually been digested, the feces may be treated with an acid solution of pepsin. This dissolves practically all the protein compounds in the feces except the true undigested food protein.

It has been pointed out in the preceding chapter (40) that in the digestion of cellulose and pentosans by bacteria in the paunch of ruminants and to a less extent in the large intestine of other animals, more or less of the carbohydrates are broken down into carbon dioxid and methan gases, which have no nutritive value. Yet, due to the method of computing digestible nutrients, these are commonly included in the amount of carbohydrates considered digestible. This does not involve any serious error even with ruminants, and with other classes of stock the discrepancy is usually negligible.

Errors are apt to occur in determining the digestibility of the ether extract, or so-called "fat," for fat is usually present in feeding stuffs in relatively small

[2]Armsby, Nutrition of Farm Animals, p. 120.

amounts and furthermore ether dissolves not only true fat but also such plant compounds as chlorophyll and waxes, and such products in the feces as the bile residues. The true fats are highly digestible, but the waxes, etc. are of rather low digestibility. Fraps and Rather[3] on studying the ether extract obtained from 18 different forage plants, found that only 42 per ct. was true fat. Of this, 66.4 per ct. was digested, while only 29.1 per ct. of the remainder (not true fat) was digestible.

The ordinary digestion trials give little information concerning the extent to which the mineral matter of feeds is actually digested and absorbed, for the compounds of calcium, magnesium, phosphorus, and iron are chiefly or wholly excreted from the body in the feces. Therefore, in a digestion trial these compounds would be reported as largely undigested, tho they may really have been digested and absorbed, and later excreted in the feces after being used in the body.

II. The Energy of Food

Tables of digestible nutrients tell what part of the food may be digested and absorbed, and thus really enter the body of the animal, but they throw no light on the uses made of the nutrients when once they are within the body. To obtain such information the *respiration apparatus* and the *respiration calorimeter* have been devised. Thru their use scientists have been able to study the uses of food in the body for the formation of flesh and fat, or for the production of work or milk.

73. The respiration apparatus.—This is an air-tight chamber, arranged with such devices that all that enters and comes from the body of the animal placed within it can be accurately measured and studied. In some cases mechanical work is performed, while in others the animal is at rest. Everything which passes into the animal—air, food, and water—is carefully measured and analyzed so that the exact intake of the body is known. The air is in turn drawn from the chamber and analyzed, and the feces and urine voided by the animal are likewise weighed and analyzed. If the intake is larger than the outgo, the animal has increased in body substance; if less, it has lost.

74. Intake and outgo during trial.—The following data, secured in an actual respiration study by Henneberg[4] with a full-grown steer weighing 1,570 lbs. will show how information is gained in such a trial.

During one day of the trial this steer ate 11.1 lbs. clover hay, 13.2 lbs. oat straw, 8.2 lbs. bean meal, and 2.13 oz. salt, and drank 123.7 lbs. water. Accurate determinations were made of the carbon, nitrogen, and mineral matter in the feed, the feces, and the urine, and of the carbon dioxid given off into the air by the steer.

The feed consumed by the steer during the 24 hours was found to contain 12.84 lbs. of carbon. This was the total intake of carbon, as, of course, none was secured from the water which was drunk. Carbon was lost from the body of the steer as follows: In the undigested material in the feces, 5.69 lbs.; in the waste products in the urine, 0.49 lb.; in the carbon dioxid exhaled from lungs and skin, 5.89 lbs.; and in the methan gas produced thru fermentations in the digestive tract, 0.04 lb. Adding these losses together we have a total of 12.11 lbs. Subtracting this total loss from the total intake of carbon, 12.84 lbs., it was found that during this time the steer's body gained 0.73 lb. in carbon content. As yet, however, there was no information regarding the form in which this carbon was

[3]Tex. Bul. 150.

[4]Neue Beiträge, Göttingen, I, 1870, p. XIX.

stored; i. e., whether it formed part of proteins built into body tissues, or whether it was stored as fat.

From the nitrogen analyses of the feed it was found that the total intake of nitrogen in the feed consumed by the steer was 0.683 lb. A loss of 0.231 lb. nitrogen occurred in the undigested matter of the feces and a further loss of 0.375 lb. in waste nitrogenous material in the urine, making a total loss of 0.606 lb. Subtracting this from the total intake of nitrogen, 0.683 lb., it was found that the steer gained 0.077 lb. of nitrogen during the day. This must have been built into the protein tissues of the body.

From the data secured it is possible to compute in the following manner the actual amount of protein and fat stored in the body of the steer during the day. To find the amount of protein stored we multiply the 0.077 lb. of nitrogen stored by 6.25, which gives us 0.48 lb. of dry protein tissue stored in the body. As carbon forms, on the average, 52.5 per ct. of protein body tissues, about 0.25 lb. of the carbon stored in the body must have been built into this protein.

Subtracting this amount of carbon from the total stored, 0.73 lb., we find that the difference, 0.48 lb., must have been stored as fat, for the carbohydrate (glucose and glycogen) content of the body of an animal at rest does not vary from day to day. This 0.48 lb. of carbon formed about 0.63 lb. of fat, for pure animal fat is on the average, 76.5 per ct. carbon.

As fresh lean meat or other protein body tissue is nearly two-thirds water, the 0.48 lb. of dry protein stored in the body equaled about 1.25 lbs. of fresh lean meat or other protein tissues. The body fat of a steer is about two-thirds fat and one-third water; hence this steer gained about 1.00 lb. of fatty tissue during the day. This careful respiration study therefore shows that from the feed consumed by the steer during 24 hours he stored in his body about 1.25 lbs. of fresh protein tissue and 1.00 lb. of fatty tissue.

By analyzing feeds, feces, and urine for mineral matter, it is possible to determine in the same manner as in the case of nitrogen, just how much total mineral matter the animal has gained or lost in a day, or how much of any particular mineral constituent, as calcium or phosphorus.

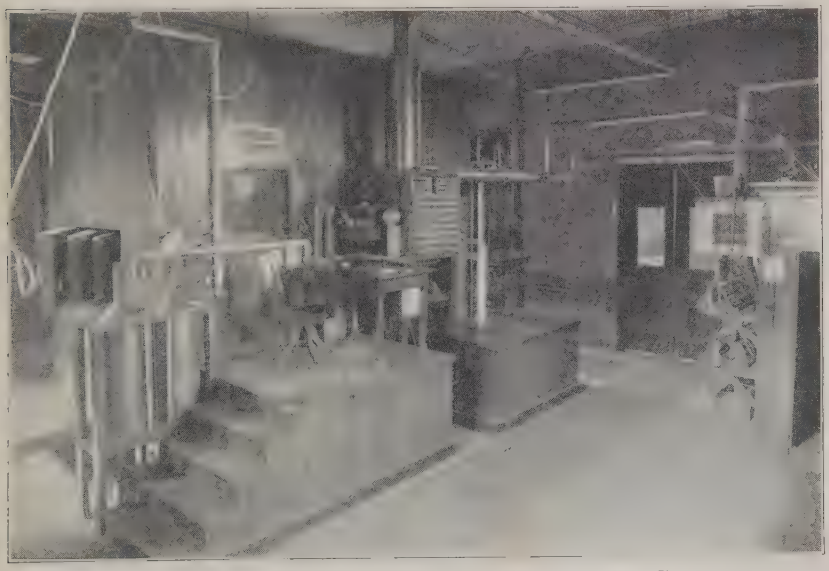
75. The respiration calorimeter.—A still more accurate means of measuring the usefulness of feeds is furnished by the *respiration calorimeter*. This is an improved and exceedingly complicated form of the respiration apparatus, in which not only the feces, urine and gaseous waste products can be analyzed, but in which the heat given off by the animal can also be accurately measured. By means of this apparatus, it is possible to find exactly how much of the gross energy of the feed the animal has been able to use in growth, fattening, work, or milk production. The first and only respiration calorimeter built in this country for carrying on experiments with large animals was erected by Armsby at the Pennsylvania Station some years ago thru the co-operation of the United States Department of Agriculture. [5]

76. Gross energy of feeds.—A mature animal may be compared to a steam engine, in which a part of the power derived from the fuel is used for the operation of the engine itself, while the surplus may perform useful work. The steam engine derives its energy from coal or wood; the animal from the feed it consumes. Both require a small amount of repair material—steel, brass, etc., for the engine, and protein and mineral matter for the animal—but the largest demand with engine and mature animal alike is for fuel. It is therefore both important and interesting to consider the relative value of feeds in terms of the fuel they can furnish the body.

[5] Expt. Sta. Record, 15, pp. 1037-50; U. S. D. A., Bur. Anim. Indus. Bul. 51.

A Steer in a Digestion Stall

In digestion trials the feces may be collected in several ways. A common manner is by means of the harness and rubber duct here shown. When it is desired merely to determine the digestibility of a feed, the urine need not be collected, as is being done in this trial. (From Pennsylvania Station.)



Respiration Calorimeter at Pennsylvania Station

Calorimeter chamber is at the left in the corner of the room. Thru the use of this apparatus the late Dr. Armsby and his associates have thrown much light on the value of different classes of feeds. (From Pennsylvania Institute of Animal Nutrition.)

ANIMALS FED FOR PRODUCTION REQUIRE CONCENTRATES

Horses at hard work, dairy cows in milk, and fattening animals all must have a considerable amount of concentrates to keep up high production.

MATURE ANIMALS CAN BE MAINTAINED CHIEFLY ON ROUGHAGE

This is not an economical method of feeding straw. However, the picture well emphasizes the fact that mature horses, cattle, or sheep which are merely being maintained can live chiefly on cheap roughage.

The value of any feeding stuff as fuel for the animal depends on the amount of energy which it will furnish when burned. As with coal, the fuel value, or gross energy, is determined by burning a weighed quantity of it in pure oxygen gas under pressure in an apparatus called a *calorimeter*. The heat given off is taken up by water surrounding the chamber in which the material is burned and is measured with a thermometer, the units employed being the Calorie and the therm.

A *Calorie* (C.) is the amount of heat required to raise the temperature of 1 kilogram of water 1°C., or 1 lb. of water nearly 4°F.

A *therm* (T.) is 1,000 Calories, or the amount of heat required to raise 1,000 kilograms of water 1°C., or 1,000 lbs. of water nearly 4°F.

The gross energy of 100 lbs. of various substances, or the heat evolved on burning them, is approximately as follows:

	Therms
Anthracite coal	358.3
Corn meal, average water content	180.3
Linseed meal, average water content	210.3
Timothy hay, average water content	181.2
Wheat straw, average water content	184.6
Pure digestible protein	263.1
Pure digestible carbohydrates	186.0
Pure digestible fat	422.0

The table shows that, on burning, 100 lbs. of anthracite coal yields 358.3 therms, or enough heat to raise the temperature of 358,300 lbs. of water 4° F., or about 8,000 lbs. of water from 32° F., or freezing, to 212° F., or boiling temperature. One hundred pounds of corn meal likewise burned yields 180.3 therms, or about half as much as coal. Linseed meal furnishes more gross energy than corn meal because it contains more fat. Roughages, such as timothy hay and wheat straw, yield just as much gross energy as a concentrate like corn meal. Digestible protein yields considerably more heat than the carbohydrates, and fat over twice as much as the carbohydrates.

77. Available energy.—The gross energy of any feed does not necessarily measure its nutritive value to the animal, because feeds which yield the same number of heat units in the calorimeter may vary in the amount of energy they actually furnish the body. This is because:

1. A part of the food is not digested, but is voided in the feces. This may be compared to bits of coal dropping thru the grate of the boiler unburned.

2. The carbohydrates, especially woody fiber, undergo fermentations in the paunch and large intestine with the formation of combustible gases, chiefly methan, which are without fuel value to the animal. (48) Even in well-constructed engines a similar loss of energy occurs in the combustible gases which escape thru the chimney without being burned.

3. Some of the protein substances digested and absorbed from the feed are broken down in the body with the formation of urea and other nitrogenous waste compounds, which are excreted by the kidneys.

(64) These have fuel value which is lost to the body. Again we may liken this loss to that which occurs in the boiler thru the creosote which, tho having fuel value, is not burned in the fire box but escapes or is deposited in the chimney.

The *available energy* of any feed, which is the only portion that is of use to the animal, is the amount of energy left after deducting from the gross energy of the feed these three losses; i. e., (1) the energy lost in feces, (2) the energy lost in urine, and (3) the energy lost in combustible gases. Some authorities prefer the term *metabolizable energy*, instead of available energy.

78. Net energy.—The available energy of the food measures its value for heat production in the animal, but does not represent its true value for other purposes. The animal must spend a part of the total available energy of any food in the work of masticating and digesting the food and of assimilating the digested nutrients. The energy so expended finally takes the form of heat and may help to keep the animal warm (88), but it is not available for other purposes in the body, since the animal has no power to convert heat into other forms of energy. Only the net amount of energy left after deducting these losses can be used for other functions in the body.

The *net energy* of any feed is the amount of energy left after deducting from the available energy the losses of energy in mastication, digestion, and assimilation of the feed. These three losses are often called the "work of digestion." They may be compared to the losses which would occur if a gasoline engine had to distil its own gasoline from crude petroleum and then get rid of the impurities which it could not use. Attention should be called to the fact that the loss of energy due to the fermentations of carbohydrates in the digestive tract in which carbon dioxid is produced, is included in the "work of digestion," as this heat which is evolved aids in warming the body. On the other hand, the loss of energy in the combustible gases produced in these fermentations is one of the losses previously deducted to get the available energy of the feed, for this is a total loss to the body.

The net energy is used by the animal, first of all, in the work of the heart, lungs, and other internal organs, and in case a surplus of net energy remains after satisfying the requirement of the animal for merely maintaining the body, such surplus may be used for producing growth, fat, milk, or wool, or in the performance of external work.

To fix the definitions for available energy and net energy in mind they may be stated thus in the form of equations.

Available energy=gross energy minus energy lost in (1) feces, (2) urine, (3) combustible gases.

Net energy= available energy minus energy lost in work of digestion.

79. Net energy of feeding stuffs.—Our knowledge of the net energy values of different feeds has been obtained largely thru the pains-

taking and laborious experiments carried on by Armsby[6] in this country with a respiration calorimeter and by Kellner[7] in Germany with a respiration apparatus. These studies have been for the most part with mature steers. While studies of this kind have as yet been carried on with but few feeds, they have already brought out facts of great interest and importance.

The following table, computed from some of these experiments, shows what becomes of the digestible nutrients and of three typical feeding stuffs when fed to cattle:

Net energy from 100 lbs. of digestible nutrients and typical feeding stuffs

Nutrients or feeding stuffs	Gross energy	Energy lost in			Available energy remaining	Energy lost in work of digestion	Net energy remaining
		Feces	Methan	Urine			
Digestible nutrients	Therms	Therms	Therms	Therms	Therms	Therms	Therms
Peanut oil (fat)	399.2	0.0	0.0	0.0	399.2	174.4	224.8
Wheat gluten (protein)	263.1	0.0	0.0	49.2	213.9	118.3	95.6
Starch (carbohydrate)	186.0	0.0	18.8	0.0	167.2	68.7	98.5
Common feeding stuffs							
Corn meal	180.3	21.2	15.9	8.1	135.1	52.2	82.9
Timothy hay	181.2	86.2	13.6	7.1	74.3	31.3	43.0
Wheat straw	184.6	107.5	15.3	4.4	57.4	47.3	10.1
Expressed in per cent							
Corn meal	100	12	9	4	75	29	46
Timothy hay	100	48	7	4	41	17	24
Wheat straw	100	59	8	2	31	26	5

The first column of the table shows the gross energy, or the total amount which would be produced on burning 100 lbs. of the digestible nutrients or of typical feeding stuffs. With the digestible nutrients no further loss occurs in the feces, but all are absorbed out of the small intestine and go into the body proper. The peanut oil contained no nitrogen, and so no nitrogenous waste from it appeared in the urine, nor did any of it form methan (marsh gas) in the paunch. To digest and assimilate this 100 lbs. of oil required 174.4 therms of energy, leaving 224.8 therms as the net energy value for growth, fattening, work, or milk production.

When 100 lbs. of wheat gluten, composed of protein, was digested and absorbed into the body, a loss of 49.2 therms occurred, due to the energy lost in the nitrogenous waste compounds excreted in the urine, which were formed from this protein. No appreciable loss occurred in methan, as proteins are not subject to the fermentations in the paunch and large intestine which produce this gas. There was therefore left 213.9

[6] Nutrition of Farm Animals, pp. 630-688; U. S. D. A. Dept. Bul. 459.
[7] Land. Vers. Stat., 53, 1900, pp. 440-468.

therms of available energy from the original gross energy of 263.1 therms. Of this amount, 118.3 therms were lost in the "work of digestion," leaving 95.6 therms as the net energy value. This could be used for building protein tissues in the body, which would be its highest use, or it could serve for the production of body fat, etc. In the case of the starch, a loss of 18.8 therms occurred in methan and a further loss of 68.7 therms in the "work of digestion," leaving 98.5 therms as the net energy value of 100 lbs. of digestible starch.

80. Relative net energy values of concentrates and roughages.—Studying the data for the typical feeding stuffs, we observe that of the 180.3 therms of gross energy furnished by 100 lbs. of corn meal, 21.2 therms of energy was lost in the undigested matter in the feces, 15.9 therms in methan gas, and 8.1 therms in the waste nitrogenous products excreted in the urine by the kidneys. The sum of these three losses was 45.2 therms. All of this was of no value to the animal, but really worse than useless, because work was required in passing this waste material thru the digestive tract and excreting it from the body. Subtracting these losses from the gross energy of the corn meal, there was left 135.1 therms of available energy. Of this available energy, 52.2 therms was lost in the "work of digestion," including masticating and digesting the corn meal and assimilating the digested nutrients. This left 82.9 therms as the net energy value of the 100 lbs. of corn meal, which could be used for repairing body tissue, for growth, for the formation of body fat, or for the production of external work.

The last part of the table shows that there was left as net energy only 46 per ct. of the original gross energy of the corn meal. While the losses of energy in the case of a rich concentrate are large, they are much greater with the roughages, for the table shows that 100 lbs. of timothy hay furnished but 43.0 therms of net energy and the same weight of wheat straw only the very small amount of 10.1 therms.

The cause for the low amount of net energy furnished by the straw is shown clearly in the lower portion of the table. While only 12 per ct. of the gross energy of the corn meal was lost in the undigested matter in the feces, in the case of wheat straw the loss in the feces amounted to 59 per ct. Furthermore, the available energy of the corn meal amounted to 75 per ct. of the gross energy, and of this less than two-fifths was lost in the "work of digestion." On the other hand, over four-fifths of the available energy furnished by the wheat straw was lost in this "work of digestion." Because of these losses, only 5 per ct. of the gross energy of the straw was left as net energy, which could be used by the animal for productive purposes.

The energy used in mastication, digestion, and assimilation is all changed to heat, which can serve to warm the body. Therefore, as is pointed out in the following chapters, such roughages as straw, corn stover, and hay have a much higher relative value for merely maintaining animals when considerable heat is needed, as for idle horses in

winter in the northern states, than for animals being fed for production, such as horses at work, growing or fattening animals, or dairy cows in milk. (**90, 113, 130, 141, 147**) Therefore, rations for idle horses and for wintering beef cattle which are not making much growth or are not being fattened may consist chiefly of such feeds, while animals being fed for large production need more net energy.

Owing to the great amount of labor involved in making studies of this character with the respiration calorimeter or with the respiration apparatus, Armsby and Kellner together determined the actual net energy values for only 21 different feeding stuffs. From the data secured in the studies of these feeds Armsby computed the net energy values for a considerable number of feeds, basing his computations, with the permission of the authors of this volume, upon the average composition of the various feeds given in Appendix Table I and the digestible nutrients given in Appendix Table III. The net energy values thus computed for some representative feeds are given on Page 122. Such net energy values are theoretically more accurate measures of the productive value of different feeds than their content of total digestible nutrients. However, such computed values are but approximations, due to the meager data yet secured. For instance, while practical feeding trials have shown corn to have a somewhat higher productive value than barley for fattening animals, the computed net energy value of barley is given as 89.94 therms, which is slightly greater than that of corn. In a few instances, like that just referred to, the computed net energy values are in fact less accurate measures of the actual relative values of feeds than the amount of total digestible nutrients the feeds furnish.

Furthermore, most of the net energy values which have actually been determined have been found in trials with mature steers. How far these values hold good for other classes of animals is a question. The few trials reported for other animals show surprising differences in some instances. For instance, Kellner found the net energy value of 100 lbs. of starch to be 81.89 therms in trials with steers, while Fingerling found it to be 151.1 therms in trials with swine. Similarly, the net energy value of peanut oil per 100 lbs. was found to be 161.71 therms in trials by Kellner with steers, and to be 386.7 therms in trials by Fingerling with swine. For wheat gluten, a similar difference was found, the net energy value being 68.45 therms for steers, and 152.3 therms for swine.[8] A comparison of the net energy values for ruminants given in Chapter VII with those for horses, given later (**447**), will show similar differences. The computed net energy values must therefore be regarded not as final, but as helpful estimates which point out important general facts concerning the relative value of different classes of feeds.

In comparing the net energy values of various feeds it should always be borne in mind that net energy is a measure of the value of a feed for

[8]Armsby, Nutrition of Farm Animals, pp. 660, 662.

productive purposes, such as the formation of flesh or fat, or the production of external work or of milk. The energy used up in the "work of digestion" all takes the form of heat and is wasted so far as such production is concerned, but this heat helps to keep the body warm. Therefore, either the available energy, which includes the energy thus spent, or else the total digestible nutrients, are better measures of the relative value of different feeds for maintaining animals, at least when there is need of a large amount of heat to warm the body, as during winter in the northern states. (**90**)

All these considerations emphasize the importance, in feeding any class of stock economically, of studying the actual results secured when the different feeds have been fed to that class of stock in extensive practical feeding trials, as reported exhaustively in Part III of this book. It will be found that conclusions based upon such trials are the safest guide in feeding operations, for they take into consideration other factors, such as palatability, quality of proteins, amount and kind of mineral matter, and perhaps the presence or absence of vitamines, all of which factors, as we shall see in later chapters, may be just as important as the amount of net energy or the amount of digestible nutrients. (**56, 94, 95-101, 104-5**)

III. Factors Influencing the Nutritive Value of Feeds

81. Differences in composition of feeding stuffs.—The figures given in Appendix Table I for the composition of any feed are in most instances averages of all analyses of normal samples of that feed which have been reported by the various stations. It is obviously important to learn what variations from these averages may be expected in the case of samples of a given feed originating in different sections of the country, grown in different years, or when gathered at different stages of maturity. Lack of space prohibits any detailed consideration of this question. However, from the mass of data compiled in Appendix Table I, including over 53,000 analyses in all, from all parts of the country, the following notes will give a fair idea of the range in the chemical composition of typical feeding stuffs.

It has been found that the composition of a crop may be influenced to a limited extent by the amount of available plant food in the soil on which the crop is grown. Climatic environment and stage of maturity are, however, the most important factors in determining the composition of a given feed. Indeed, with some feeds they influence the content of nutrients to such a degree that an average of analyses from all sections of the country or at all stages of maturity is of little value for any purpose. Of the cereals, wheat is the most variable in composition, being profoundly influenced by climate, especially in its protein content. The analyses for this grain from different sections of the country are therefore given separately in Table I. It is there shown that while the aver-

age crude protein content of wheat from the northern plains states is 13.5 per ct., wheat from the Atlantic states contains only 11.7 per ct. and that from the Pacific states but 9.9 per ct. crude protein. The same extended study shows that climate exerts little or no influence on the chemical composition of corn, providing the crop matures, the average for the various sections showing no appreciable difference in content of the several nutrients. Grindley of the Illinois Station[9] has shown that samples of corn and wheat from the same region may vary 10 per ct. and sometimes even more in their content of protein or fat. The nitrogen-free extract is less variable, while fiber shows still larger differences than protein or fat. The same general tendencies as to local variations hold with the other cereal grains.

Obviously, the amount of moisture in grain or any other feed directly affects the amount of nutrients it furnishes. Of the cereals, corn commonly varies most in water content. Therefore separate averages are given in Appendix Tables I and III for dent corn of the various grades, based on the percentage of water contained.

The roughages are even more variable in composition than the cereals, owing to the fact that, besides climate, their composition is often greatly influenced by the stage of maturity, the manner of curing, and the moisture content. Analyses of corn fodder and corn stover show a water content ranging from over 50 per ct. in field-cured material in wet seasons down to 10 per ct. or less in arid regions or where cured under cover in a dry season. To show the difference in nutritive value of these extremes it may be stated that corn fodder or stover containing 10 per ct. water will carry 80 per ct. more nutrients per 100 lbs. than a sample of the same forage containing 50 per ct. water! To overcome this error so far as possible, separate averages are given for very dry and for ordinary field-cured samples of these feeds in Appendix Table I.

The general rule that immature plants contain a much larger *proportion* of crude protein than when mature is well illustrated by analyses of samples of alfalfa cut at various stages of maturity by Dinsmore at the Nevada Station[10] and cured until they were somewhat drier than normal hay. The dried alfalfa cut when 3 inches high, a stage at which it is often grazed, carried 34.6 per ct. crude protein and only 43.4 per ct. total carbohydrates. As the crop matured the protein content of the hay therefrom decreased and the carbohydrates increased, till the sample cut when seed was beginning to form contained only 14.1 per ct. crude protein, while the carbohydrates had increased to 68.1 per ct. Immature plants usually contain much more water than the same plants when more mature. On account of such wide differences in composition the authors have, wherever possible, given in Appendix Table I the averages for roughages at different stages of growth. (See averages for corn fodder, timothy hay, Kentucky bluegrass, red clover, etc.)

[9] Ill. Bul. 165.

[10] Nev. Rpt. 1907.

It is shown in later chapters that as the grasses and legumes mature their content of fiber materially increases, and as a consequence the feed becomes less digestible and usually of lower value. However, the large accumulation of starch which occurs in the corn plant as it ripens gives the more mature form of that plant a greater total feeding value. (27)

If green forage is cured without waste and in a manner to prevent fermentation, the mere drying does not appreciably lower its digestibility. Ordinarily, however, in curing forage much of the finer and more nutritious parts is wasted, and dews, rain, and fermentations effect changes which lower digestibility. Also more energy is required in masticating dry forage and passing it thru the digestive tract than in the case of green fodder. These facts explain why green forage commonly gives better results than dry forage. The long storage of fodders, even under favorable conditions, decreases both their digestibility and palatability. Hay browned by heating shows increased digestibility of fiber but decreased digestibility of crude protein and nitrogen-free extract.

82. Influence on digestibility of amount of feed eaten.—Animals tend to digest their food somewhat more completely when given a maintenance ration than when on full feed. This may be due to the more rapid movement of the food thru the digestive tract or to a less complete absorption of the digested nutrients when present in large amount. Jordan[11] found that sheep digested 4.7 per ct. more of the dry matter when given a half ration than when fed a full ration. Mumford, Grindley, Hall, and Emmett[12] of the Illinois Station, on feeding steers clover hay and corn in varying proportions, found that those fed a maintenance ration digested 75.4 per ct. of the dry matter; those fed one-half more, 71.6 per ct.; those fed twice the maintenance ration, 69.4 per ct.; and others on full feed, consuming two and one-fourth times as much as the first lot, 65.9 per ct. of the dry matter of the ration. The difference in digestibility was greatest in the case of the carbohydrates. The steers on full feed digested the crude protein and fat nearly as well as those getting the maintenance ration. When a large proportion of roughage and concentrates was fed, there was little difference between the digestibility of a liberal and a scant ration.

Eckles[13] of the Missouri Station found that the dairy cow digests a maintenance ration somewhat better than a heavy ration. Under normal conditions, in feeding farm animals for the production of meat, milk, or work, other economic factors, which will be treated in later chapters, more than offset the slightly better utilization of feed when a scant ration is fed.

83. Influence of preparation of feed on digestibility.—Grinding, cracking, and rolling grain increase digestibility only in the case of hard seeds which would otherwise pass thru the digestive tract unbroken, or with animals unable to chew their food properly. The saving thru

[11]N. Y. (Geneva) Bul. 141. [12]Ill. Bul. 172. [13]Mo. Res. Bul. 7.

thus preparing grain will therefore depend upon the kind of grain and the class of animals to which it is to be fed. Detailed conclusions on this question are presented in Chapter XVI (**423**) and in the respective chapters of Part III.

Contrary to much popular opinion, there is neither an increase in digestibility nor any other saving thru cooking most feeds for stock. (**425, 922**) In fact, cooking usually lowers the digestibility of the crude protein of feeding stuffs. The only apparent exception to this conclusion, is that for swine, potatoes, field beans, and velvet beans are considerably improved by cooking.

A comparison of the digestion coefficients for various kinds of silage with those for the green forages from which the silage was made shows that ensiling tends to decrease rather than increase the digestibility. The exceedingly favorable results from silage feeding are therefore due to the palatability of the silage, its beneficial effect on the health of the animals, and the fact that less feed is wasted than with dry fodder.

Neither the frequency of feeding, the time of watering, nor the amount of water drunk appears to influence digestibility. Moderate exercise tends to increase digestibility, but excessive work lowers it.

The flow of saliva and the other digestive juices is checked by fright. On the other hand, kind treatment and palatability of food should favorably influence digestion. Under skillful care animals show remarkable relish for their food, and it is reasonable to conclude that better digestion ensues, tho no confirmatory data can be given.

84. Influence of proportion of the several nutrients.—The addition of a large quantity of easily digested carbohydrates, such as sugar and starch, to a ration containing much roughage may reduce the digestibility of its crude protein, fiber, and nitrogen-free extract.

Such *depression of digestibility* occurs with ruminants when less than 1 part of digestible crude protein is present to every 8 parts of digestible non-nitrogenous nutrients (carbohydrates plus fat $\times$ 2.25). With swine the nutritive ratio may be wider before the digestibility is affected. An explanation offered for such depression of digestibility is that when a large proportion of soluble or easily digested carbohydrates is fed, the bacteria in the digestive tract which normally decompose cellulose to secure food then attack instead the more readily available sugars or starch. (**40**) Not only is the digestibility of the cellulose, or fiber, consequently lowered, but also that of the crude protein and nitrogen-free extract, for the unattacked cellulose cell walls protect the proteins and carbohydrates contained therein from the action of the digestive juices. This depression does not occur when nitrogenous feeds, such as oil meal, are added along with the starch or sugar, thus preserving the balance between protein and non-nitrogenous nutrients. It is assumed that this is due to a stimulation of the bacteria by the addition of more protein, so that, invigorated, they attack the fiber of the food again.

Adding nitrogenous feeds to roughages, such as hay, straw, etc., does not increase the digestibility of the roughage. Neither does the addition of fat to a ration increase the digestibility of the other constituents. It has been found[14] that feeding fat in excess of 1 lb. per 1,000 lbs. live weight or feeding pure fat or oil in unemulsified form may cause digestive disturbance. Salt does not affect digestion, tho it may cause animals to eat more food and may improve nutrition.

The addition of dilute acids, such as sulphuric acid or lactic acid (the chief acid in sour milk and in silage), does not influence digestibility. This is important because silage contains considerable free acid.

85. Class of animal, age, and breed.—Ruminants—the ox, cow, sheep—digest the same kind of forage about equally well. Kellner,[15] however, showed that the ox is able to digest as much as 11 per ct. more of the less digestible roughages, such as straw, than is the sheep. He ascribed this difference to the fact that the contents of the last part of the intestine of the ox remain more watery and hence are subject to more complete fermentation. The more easily digested a feeding stuff is, the less difference will there be in its digestion by these various animals. For the great majority of feeding stuffs the same digestion coefficients may be used for the sheep and ox.

The horse and pig digest less fiber than the ruminant, in whose paunch the coarse feeds undergo special preparation and digestion. The richer the feed, the more nearly do the digestive powers of the horse approach those of other farm animals. Swine digest the concentrates fully as well as do the ruminants, but make only small use of the fiber.

In general, age does not, in itself, influence digestibility, tho young farm animals cannot utilize much roughage until their digestive tracts are developed. It is shown in later chapters that growing pigs chew corn more thoroly until they reach a weight of about 150 lbs. and calves masticate grain more completely up to an age of 6 to 8 months than they do later, facts which should be considered in determining whether to grind their feed.

The digestion of old animals is often indirectly impaired by poor teeth, which make the proper mastication of their food impossible. Breed has no influence upon digestibility. Individual animals may, however, show considerable difference in their ability to digest the same ration, tho ordinarily the digestibility of a given ration by different animals of the same race will not vary by more than 3 to 4 per ct.

86. Summary.—The foregoing discussions make it evident that average figures for the composition of any feeding stuff are but approximately correct when applied to a particular lot of the feed. This likewise applies to the expression of its nutritive value, whether stated in terms of digestible nutrients or net energy. In other words, different lots of any feeding stuff vary in feeding value, the same as different samples of coal

[14]Ernähr. landw. Nutztiere, 1907, p. 51.

[15]Land. Vers. Stat., 63, 1906, p. 313.

vary in fuel value. Owing to the expense of obtaining analyses, it is out of the question for any but the most extensive feeders to have their particular feeds analyzed, just as only the large manufacturer can afford to have samples of coal analyzed to determine their fuel value before purchasing. With the cereals and the roughages the general feeder must, therefore, rely on that average given in tables of digestible nutrients or net energy which corresponds most closely in his judgment to the feed at hand. In purchasing commercial concentrates, now sold in vast quantities everywhere, it is fortunately possible in most sections of the country to secure standard brands, whose composition is fully guaranteed by the manufacturer. (Chapter XI)

CHAPTER IV

MAINTENANCE OF FARM ANIMALS

I. Requirements for Body Fuel

Farm animals are given food in order that they may convert it into such products as meat, milk, wool, and work, which are useful to man. However, just as a factory must be supplied with power to keep the machinery in motion before any products can be turned out, to make continued production possible with the animal, enough food must first be provided to maintain all necessary life processes.[1] This amount of food, which is required merely to support the animal when doing no work and yielding no material product, is called the *maintenance ration.* A respiration trial conducted with an animal receiving a maintenance ration would show that its body was neither gaining nor losing protein, fat, or mineral matter.

On the average, fully one-half of the feed consumed by farm animals is used simply for maintenance, only the remaining half being turned into useful products. Knowing this, the intelligent feeder will realize that it is just as important to understand the principles governing the maintenance requirements of farm animals as those controlling the production of meat, milk, or work. The determination of the minimum amount of nutrients required for maintenance is also of great scientific importance, for it is impossible to find the true relative value of feeding stuffs for production without first subtracting the amounts used in mere maintenance.

To maintain an animal at rest the ration must furnish sufficient amounts of the following: (1) Fuel to maintain the body temperature; (2) energy to carry on such vital processes as the work of the heart, lungs, etc.; (3) protein to repair the small daily waste of nitrogenous tissues; (4) mineral matter to replace the small but continuous loss of these materials from the body; (5) vitamines, which recent investigations have shown to be just as necessary as the nutrients previously considered essential. For all classes of animals, other needs which must be supplied are air, water, exercise, and sunlight.

87. Body temperature.—While cold-blooded animals maintain their temperature but little above that of the surrounding air or water, the temperature of warm-blooded animals ranges from 98.4° to 105.8° F., a height which the air reaches only during the hottest summer days. It is therefore evident that heat must be continuously produced within the body to keep it at such temperatures.

[1] Armsby, Penn. Bul. 111.

The normal temperature of different animals of the same species may vary considerably. On the other hand, the temperature of an individual animal, if healthy, varies only within a narrow limit, a departure of even 1 degree from normal with farm animals generally indicating some bodily derangement. The normal body temperature of mature horses ranges from 98.4°-100.8°F. (36.9°-38.2°C.) and averages about 100.2°F. For mature cattle the range is from 100.4°-102.8°F. (38.0°-39.3°C.) and the average about 101.5°F. The range of normal temperature is greater in sheep and swine than in horses and cattle. In sheep the range is 101.3°-105.8°F. (38.4°-41.0°C.) and the average about 103.5°F. In swine the range is 100.9°-105.4°F. (38.2°-40.7°C.) and the average about 102.6° F.

88. Heat production.—Heat is produced by all the decompositions or oxidations taking place in the body, whether of food yet within the digestive tract or of nutrients in the muscular tissues or the glands. We have seen previously that much heat may be evolved, especially with ruminants, in the fermentation of cellulose and other plant compounds in the digestive tract. (40) The remainder is produced in the tissues of the body by the following processes: Thru breathing, the oxygen of the air is brought to the blood. Floating in the blood stream are myriads of microscopic bodies, called red blood corpuscles, which owe their color to hemoglobin, an iron-containing protein. This hemoglobin absorbs the oxygen and holds it loosely. As the oxygen-laden blood permeates the capillary system it gives up the oxygen to the living body cells, where it is used for the combustion of a portion of the body nutrients, with the result that heat is formed.

Unlike the burning of fuel in a stove, the oxidations in the body take place at a comparatively low temperature. As a result of the combustion in the body, where before there were glucose, fats, and proteins in the tissues, there now remain carbonic acid gas, water, and urea, the latter substance representing the principal nitrogenous waste of the protein nutrients. In still another respect body oxidations differ radically from ordinary burning of fuel. In a furnace the wider the draft is opened, increasing the supply of oxygen, the more rapid will be the combustion. However, in the body, so long as there is a normal supply of oxygen, the rate of burning of the food nutrients is independent of the supply of air. Hence the greater intake of oxygen in unusually deep breathing will not in itself cause an increase in heat production, tho the increased muscular work in such breathing may lead to an increased production of heat.

As has been shown in the preceding chapter (78-80), all the energy used up in the various forms of internal work of the body is finally changed to heat. Tho this energy is lost so far as useful production is concerned, the heat generated helps to warm the body. The amount of heat so produced is considerable. Even with such an easily digested feed as corn, over one-third of the total energy which the digestible nutrients

furnish is converted into heat in the work of masticating, digesting, and utilizing it. With roughages like hay and straw the proportion is much larger. However, in the case of animals exercising normally the larger part of the body heat is produced in the muscular tissues, since all muscular contraction is caused by the oxidation, or burning, of nutrients in the muscles. Even when the muscles are not actively contracting, some heat is being generated in them, for they are even then under a greater or less degree of tension.

When an animal is given no food, the heat needed to warm the body, the net energy required to carry on the vital processes, and the protein and mineral matter necessary for the repair of the active tissues must all come from nutrients previously stored within the body. The small supply of glycogen in the liver and muscles is probably first used as fuel, but this is soon gone. (60) Fat is the animal's chief reserve fuel, stored when food is abundant, against times of scarcity, and is therefore the main source of both heat and energy during starvation. When the supply of fat begins to fail, the muscles and other protein tissues are broken down more rapidly to furnish heat and energy, and the animal finally perishes thru the impairment of its organs and the lack of body fuel to carry on the functions of life. Carnivora, or flesh-eating animals, withstand hunger longer than herbivora. While dogs and cats have lived until their weights were decreased 33 to 40 per ct., horses and ruminants will die when their weight has been reduced 20 to 25 per ct. Men have voluntarily fasted for over a month, and dogs have survived fasts of from 90 to 117 days without permanent ill effects. The age of the animal influences the time at which death occurs from starvation, young animals losing weight more rapidly and dying after a smaller loss of weight than old ones.

89. Regulation of body temperature.—In order to keep the temperature constant under varying external conditions and with daily supplies of food differing in amount and heat producing power, warm-blooded animals must possess a highly efficient means of heat regulation. This is under the control of the nervous system and is accomplished by governing both the loss and the production of heat.

The most important means of controlling the loss of heat is by varying the circulation of the blood near the surface of the body. When the body temperature rises, more blood flows to the capillaries of the skin, increasing the loss of heat by radiation and conduction. It is this which causes the flushing of the skin commonly observed when one becomes heated. This means of regulation may be compared to opening the windows when a room becomes too hot. If this means of control is not sufficient to keep the body temperature normal, sweat is produced, the evaporation of which cools the surface of the body. If the animal has no sweat glands, as in the case of the dog, or only a few, as in the case of swine, it will begin to pant, thus increasing the evaporation of water from the mouth and the vaporizing of water from the lungs. If

the air temperature falls again these processes are reversed. In addition to these means of controlling the loss of heat, the clothing of man, and the hair, wool, feathers, or thick skin of animals check and control its loss from the body.

The relative importance of the various channels thru which heat is lost depends upon various conditions, including the species of animal. In humans,[2] about 73 per ct. is lost by the radiation and conduction from the skin, 14 per ct. by the evaporation of water from the skin, 7 per ct. by vaporizing water from the lungs, 4 per ct. by warming the air breathed out, and 2 per ct. in the feces and urine.

When the temperature of the air falls below a certain point, another means of heat regulation must be brought into action; i. e., an increase in the rate at which heat is produced in the body. This is similar to increasing the fire in a room, if it is still too cold after the windows are all closed. This greater heat production is brought about by increasing the oxidations of nutrients in the tissues of the body. This may be accomplished partly more or less voluntarily, but may also be entirely involuntary. On cold days, for example, animals eat more heartily and take more exercise than in warm weather, both of which result in the formation of more heat. A low external temperature also causes an involuntary stimulation of the oxidations going on in the tissues, which may even become visible in the shivering of the chilled animal, that is the outward manifestation of increased muscular contractions, started solely to produce more heat.

Because the loss of heat is largely controlled by the clothing he wears, man has, in some measure, lost his power of heat regulation. With many of the warm-blooded animals, however, this power is highly developed.

90. Heat and energy required for maintenance.—Experiments have shown that with a mature animal being maintained at rest in the stall the requirement for fuel to keep up the body temperature ordinarily greatly exceeds the amount of net energy needed for the internal work of the body organs. As will be shown later (448), Zuntz found that to maintain the horse at rest only one-third of the total energy of the ration need be supplied in the form of net energy, the remainder serving simply as body fuel. Hence, except for the pig, the maintenance rations of farm animals may consist largely of roughages, such as hay and straw, which furnish abundant heat, but do not yield much net energy. (78-80) Since the ration must furnish at least a minimum amount of net energy, animals cannot be maintained on such feeds as wheat straw alone, which furnish no net energy to the horse and but little to the ruminant.

Due to differences in temperament, there is considerable variation in the maintenance requirements of different individuals of the same size and species, kept under the same conditions. As restlessness causes greater muscular activity and thereby uses up more body fuel, a quiet animal requires less food for maintenance than a nervous, active one.

[2]Howell, Text Book of Physiology, 1907, p. 861.

This is probably the chief reason why a quiet steer which will "eat and lie down" makes more economical gains than a wild or nervous animal. This effect of difference in temperament also explains why some horses are much "easier keepers" than others. It has been found that the presence of flies caused a horse to burn 10 per ct. more fuel in its body than normally, a fact which has a practical bearing in feeding stock.[3]

Armsby[4] found that steers when standing required 41 per ct. more nutrients for maintenance than when lying down. This is partly due to the work of maintaining the body upright and also to the greater muscular movement of the animal when standing. The condition of an animal influences the maintenance requirement somewhat, a fat animal requiring more feed for maintenance than a lean one of the same weight or of the same body surface.[5]

It has been shown on the preceding page that the chief loss of heat from the body is by radiation. Such loss of heat from solid masses has been found by scientists to be proportional not to their weights, but to their surfaces. This is because large bodies have less surface per pound than small ones. Theoretically, therefore, maintenance rations for animals of various sizes should be computed on the basis of the body surface and not live weight. Since it is difficult to measure the surface of an animal's body, the body surface may be computed by the well-known geometrical law that the surfaces of solids are proportional to the squares of the cube roots of their weights. In scientific trials, maintenance rations have usually been computed on this basis.* However, Armsby found in his trials that the actual maintenance requirements of steers of various weights and ages correspond as well with their live weights as with their body surfaces, as computed by this formula. In the Morrison feeding standards the maintenance requirements are stated per 1,000 lbs. live weight, assuming that this will give results of sufficient accuracy in figuring rations under practical conditions.

The rate at which heat is lost from the body by radiation also depends on the difference between the air temperature and the body temperature. Due to this Trowbridge, Moulton, and Haigh found at the Missouri Station[6] that the maintenance requirements of an animal are less in the spring than in the winter. In the summer they are higher than in spring, due to the extreme heat and the presence of flies. They also found that unthrifty animals required much more feed for maintenance than healthy ones. The maintenance requirement of young animals was greater than of older ones of the same weight.

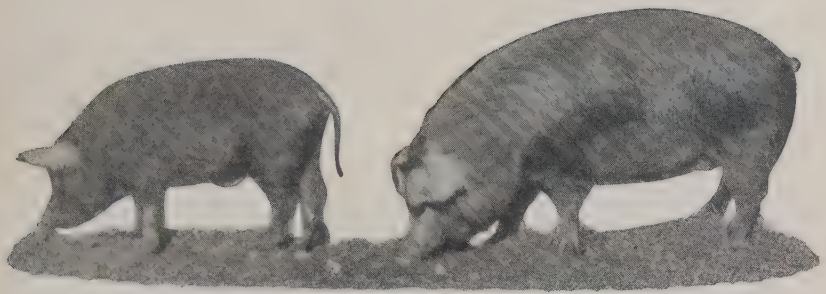
Exposure to cold winds, especially with animals having scant coats,

[3]Landw. Jahrb., 23, 1894, p. 161.

[4]Jour. Agr. Research, 13, 1918, pp. 43-57.

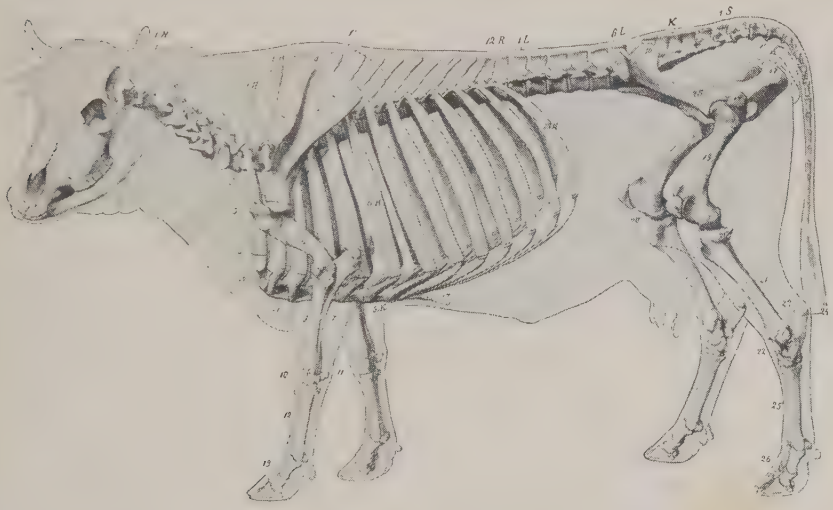
[5]Armsby, Jour. Agr. Research, 11, 1917, pp. 451-72. [6]Mo. Research Bul. 18.

*Moulton states (Mo. Res. Bul. 30) that the maintenance requirements of fat steers are more nearly proportional to the five-ninths power of their weights, and of steers in medium to thin condition to the five-eighths power of their weights.



QUALITY OF PROTEINS MAY BE AS IMPORTANT AS THE AMOUNT

Animals need not only plenty of protein in their food, but also proteins of the right kind or quality. The pig on the left received plenty of protein, but his ration consisted of only grain and grain by-products, supplying unbalanced proteins. The pig on the right, which is of the same age, received a ration of grain plus skim milk, which supplied well-balanced proteins. (From Wisconsin Station.)



FARM ANIMALS NEED AN AMPLE SUPPLY OF MINERAL MATTER

Over 90 per ct. of the mineral matter in the skeleton consists of calcium and phosphorus. In certain rations the amount of these mineral elements may be insufficient for health. (From Ellenberger.)

DEAD CALF FROM COW FED RATION LACKING CALCIUM

Cows fed "balanced rations" with straw from the small grains as the only roughage, along with grain and grain by-products, usually produce dead or weak offspring, due to the lack of calcium in such rations. See Pages 66-7. (From Wisconsin Station.)

THRIFTY CALF FROM COW FED PLENTY OF CALCIUM

When plenty of calcium is furnished by adding legume hay to such rations, thrifty calves are produced. The trouble is largely prevented by adding calcium in the form of a mineral supplement. (From Wisconsin Station.)

greatly increases the radiation of heat. Animals with coats wet by cold rain or snow lose additional heat from their bodies, for the cold water which falls on them must be warmed and evaporated by heat generated thru the burning of food. With the well-fed fattening animal, the greater loss of heat thru these causes may not produce any waste of food, for much more heat is being generated in the mastication, digestion, and assimilation of the heavy ration than is normally needed to warm the body. In the case of animals on a maintenance ration, whose chief demand is for body fuel, such exposure will necessitate an increased consumption of feed to serve as fuel. On the other hand, too high a stable temperature leads to loss of appetite and induces sweating.

II. Requirements for Protein

91. Protein waste from the body.—In view of the high cost and relative scarcity of crude protein in feeding stuffs, it is important to know the minimum amount of this nutrient required for maintenance. There is at all times an excretion of nitrogen from the animal body by way of the urine. With a well-nourished animal this excretion is relatively large, the amount depending chiefly upon the quantity of nitrogen supplied in the food. If all food is withheld from such an animal, the nitrogen excretion decreases rapidly at first, until the supply of amino acids in the blood and tissues, which have not yet been built into body protein, is lowered to a minimum. The nitrogen waste in the urine then slowly decreases until it reaches a level which remains quite constant so long as heat and energy are furnished by the body fat. When the supply of the latter begins to fail, the muscles and other protein tissues must thereafter not only furnish protein for the repair of the vital body machinery but must also supply the necessary heat and energy; consequently they waste more rapidly until death follows.

When animals are fed exclusively on nitrogen-free nutrients, such as the sugars, starches, fats, etc., the waste of fat from the body is materially lessened, and the waste of the nitrogenous tissues of the body, such as the muscles, is somewhat reduced, tho not entirely stopped. On account of this sparing of the body substances, animals forced to live on such diet survive longer than those wholly deprived of food. Yet because of the continuous small waste of protein from the tissues of the body, animals nourished solely on fats and carbohydrates cannot long survive.

92. Feeding protein alone.—We might expect that when protein only is fed to a fasting animal, in an amount corresponding to the quantity lost daily during starvation, it would replace the protein wasted from the tissues, and the animal thus be brought to nitrogen equilibrium; that is, it would excrete as much, but no more, nitrogen than was contained in the food. However, when protein is fed under such conditions, the amount of nitrogen excreted at once rises, and tho the loss of nitrogen from the tissues is reduced, nitrogen equilibrium is not reached. When

practically pure protein is fed, the loss of nitrogen can be checked only if the supply is far in excess of the waste from the starving body. It is assumed that this increase in nitrogenous waste when protein is fed in such large proportion is due to a flooding of the tissues with amino acids, the products of protein digestion, and a consequent stimulation of the activities of the body cells. (**11, 49**) However, the food protein so decomposed is not entirely lost to the animal. Not only may it be burned as body fuel, thus saving the body fat, but, after the splitting of the nitrogen from the molecules of protein or of amino acids, the non-nitrogenous residue which remains may be converted into glucose and finally into glycogen or fat. Carnivora, or flesh-eating animals, have lived for long periods on washed lean meat, consisting chiefly of protein, with only a small amount of fat and a trace of glycogen. Since plant tissue is rich in carbohydrates, such experiments have not been possible with the herbivora, or plant-eating animals.

93. Protein required for maintenance.—The preceding discussions have pointed out the functions of protein in the body under various conditions. Let us now pass to a question of much practical importance—the amount of protein required to maintain animals at rest, when fed along with sufficient carbohydrates or fats to meet the needs of the body for fuel. When enough of these nitrogen-free nutrients is supplied, the amount of protein required to prevent loss of nitrogen from the body is much less than where the ration is nearly pure protein. In trials with dogs Voit[7] found that from 2.6 to 3.3 lbs. of lean meat per day was required to check the loss of protein from the body when lean meat was fed alone—practically an exclusive protein diet. When carbohydrates or fat was added, only one-half to one-third as much lean meat was needed. Since the digestible portion of the crude fiber and likewise of the pentosans can serve as body fuel (**48**), these nutrients to some degree decrease the waste of nitrogen in the same manner as does a supply of the more easily digested sugars and starch.

Experiments show that a pound of carbohydrates has somewhat greater protein-sparing action than a pound of fat, a surprising fact when we remember that, on burning, fat produces over twice as much energy as do carbohydrates. (**76**) Evidently there is no relation between the fuel values of these nutrients and their protein-sparing power. This is perhaps because glucose, which is needed by the body, is formed with difficulty from fat.[8]

By feeding rations ample in carbohydrates and fat, some investigators have succeeded in reducing the requirement of nitrogenous matter to slightly more than the normal nitrogen waste of the body during starvation. At the Pennsylvania Station[9] Armsby found in experiments with steers, covering 70 days, that from 0.4 to 0.6 lb. of digestible protein daily per 1,000 lbs. of live weight was sufficient to maintain the nitrogen

[7]Ztschr. Biol., 5, 1869, p. 352. [9] Principles of Animal Nutrition, 1903, p. 142.
[8]Skand. Archiv. Physiol., 14, 1903, p. 112.

equilibrium. Contrary to the observations of some of the earlier investigators, no ill effects followed this small supply of protein. Wintering cattle on feeds poor in crude protein—straw, inferior hay, corn stover, etc.—as practiced by many farmers, confirms this finding.

In general, it is not wise to supply only the theoretical minimum of protein to animals for extended periods for the following reasons: As we have seen (**81, 85**), it is essential to make some allowance for the difference in composition of feeding stuffs and the varying capacities of animals to digest and utilize the nutrients in the ration. Besides supplying protein to replace the daily waste from the organs of the body, sufficient must also be given to maintain the growth of the nitrogenous hair, hoofs, wool, etc. When the ration has too wide a nutritive ratio, the digestibility of the feed is decreased. Moreover, certain proteins of unbalanced composition fed as the sole source of nitrogen will not suffice to maintain an animal. For example, in numerous experiments animals have never been maintained successfully on gelatin, which lacks two amino acids and contains only small amounts of others. As we have little knowledge concerning possible deficiencies in the mixture of proteins supplied in the different individual feeding stuffs, it is advisable to make allowance for waste which may occur if the feed contains low amounts of some of the amino acids essential for maintenance. It is also a well-known fact that in general protein is a cell stimulant, and a supply somewhat above the minimum promotes the well-being of the animal.

The wisdom of not attempting to limit the protein supply to the theoretical minimum for long periods is shown by the experience of Haecker[10] of the Minnesota Station. During many years of patient study he found that dairy cows under good care and otherwise liberal feeding would for long periods continue a good flow of milk on a surprisingly small allowance of crude protein. After some years of such feeding, however, their vitality was so depleted that they became physical wrecks long before their time. These studies led Haecker to raise the amounts of crude protein in his feeding standards for the dairy cow above his earlier allowances, tho his recommendations are still below the Wolff-Lehmann standard, as is shown elsewhere. (**182**)

Even when sufficient protein is fed to insure good health, the amount required to maintain mature resting animals is not large compared with the need of carbohydrates and fat for body fuel. Maintenance rations for such animals may therefore have a relatively wide nutritive ratio. For example, Kellner recommends for the maintenance of the mature ox at rest a supply of 0.6 to 0.8 lb. of digestible protein per 1,000 lbs. live weight. Armsby places the maintenance requirements for both the horse and the ox even lower, recommending but 0.5 lb. digestible protein per 1,000 lbs. live weight in his standards for maintenance. (**172**)

94. Can amids replace proteins?—It has previously been explained that the amids include those nitrogenous compounds which are less complex

[10] Minn. Buls. 71, 79, 140.

than the true proteins. Whether these amids can be used for the same purposes in the body as are the proteins of the food, has long been a disputed question. If the mixture of amids in a feeding stuff contains the proper proportion of the various amino acids (the protein building stones), it now seems certain that these amids can be used the same as the true proteins.

For example, about one-third of the crude protein in legume hays usually consists of amids. Nevertheless, the crude protein in these feeds is much more efficient for maintenance, growth, or milk production than the crude protein of the cereal grains, which contains but a very small proportion of amids. Similarly, about half the crude protein in corn silage consists of amids, largely formed by the breaking down of proteins in the ensiling processes, for amids form only about 15 per ct. of the crude protein in dried corn fodder. Yet on the dry basis, corn silage is more valuable than corn fodder for stock feeding.

From these facts it appears logical in making up balanced rations for stock, to base the computations on the total amount of digestible *crude protein,* as is advocated in the Morrison feeding standards. In view of our present knowledge it seems unwise to exclude entirely the value of the amids as sources of nitrogen for body uses, as is done in the Armsby and Kellner feeding standards.

III. Requirements for Mineral Matter

At the present time, the importance of mineral matter for live stock is receiving much popular attention, due chiefly to striking results which have been secured in recent experiments by nutrition experts. As a consequence, many proprietary mineral mixtures are now being widely advertised, often with extravagant claims. It is therefore essential that stockmen understand clearly just how much is known concerning the mineral requirements of live stock. They can then supply any needed mineral supplements for their stock at low expense, without spending unnecessarily large sums on expensive preparations.

95. Importance of mineral matter.—That the mineral matter is of the greatest importance to animals is shown by feeding rations freed as far as possible from it, in which case they die of mineral starvation. Indeed, animals thus fed generally perish sooner than when no food is given. During such starvation the nervous system first suffers in a perceptible manner; marked weakness of the limbs, trembling of the muscles, convulsions, and great excitability result.

Mineral matter is found in all the vital parts of the body. The nuclei of all cells are rich in phosphorus, and the skeleton is composed largely of calcium (lime) combined with phosphorus. Blood deprived of its calcium does not clot. The blood serum is rich in common salt and other salts of sodium, while the red blood corpuscles are rich in potassium compounds. The power of the blood to carry oxygen is due to hemo-

globin, an iron-protein compound in the red corpuscles. In the stomach the pepsin acts only in the presence of an acid, normally hydrochloric, derived from the salts of this acid present in the blood.

96. Mineral compounds control life processes.—In some mysterious manner, possibly by carrying electric charges which stimulate the body cells,[11] the mineral compounds of the body direct its various vital processes. A simple experiment often performed in the laboratory will illustrate the important functions of the mineral elements in life. If the heart, still beating, is removed from a frog and placed in a solution of pure sodium chlorid (common salt), its beats soon fade out. Now if a small amount of a calcium salt (lime) be added to the solution, the heart will at once begin to beat again, and will continue in rhythmical contraction for some time. Unless a small amount of a potassium salt is also added, the beat will not, however, be normal, but the heart will fail to relax quickly and completely enough after each contraction. Therefore, if potassium is not added the relaxations become more and more feeble, until the heart stops in a contracted state. Not only must potassium be present, but there must be a correct proportion between the amounts of calcium and potassium. If too much potassium is added, the heart will fail to contract properly, and finally will again stop beating, but this time in a state of complete relaxation.

Similarly, the other vital processes are dependent not only on the presence of various mineral salts, but also on a proper relationship between them. Therefore it will be seen that unless the amount of these mineral salts in the blood is kept normal, serious consequences will follow. In large measure the kidneys protect the animal against an unbalanced mineral matter content in the blood by promptly excreting any excess of various salts which may be present. However, when the food continually furnishes the blood an unbalanced salt mixture, the kidneys may be unable to keep the blood composition normal, with resultant injury to the animal. For instance, magnesium and calcium seem antagonistic in their action, and in voiding the excess of magnesium the body loses calcium. Given in excessive amount for long periods, feeds which contain much magnesium in proportion to calcium, such as wheat bran and middlings, are said to cause a weakening of the bones, leading to such troubles as "bran disease" or "miller's horse rickets."

Appendix Table VII sets forth the mineral constituents of representative feeding stuffs.

97. Mineral requirements for maintenance.—The common feeding stuffs contain all the necessary mineral salts, at least in small amounts. As a rule, the roughages, except some of the straws, are much richer than the grains in mineral matter. Moreover, the body is probably able to use many of the mineral compounds over and over, taking them back again into the circulation after having been used. Therefore, for

[11]Forbes, Ohio Tech. Bul. 5.

animals which have finished their growth, rations containing plenty of good-quality roughage will usually furnish sufficient mineral matter, except common salt. As shown later, it is in general always advisable to supply farm animals common salt in addition to that in their feed. Since over 90 per ct. of the mineral matter of the skeleton consists of calcium (lime) and phosphorus, these mineral constituents may also fall short in some rations, especially in those for young, growing animals, which need an abundance for building their skeletons. As is advised later (**916**), it is usually wise to keep a supply of a suitable mineral mixture before pigs, at least when confined to pens. Under certain conditions there may be a lack of iodine in the feed, which may cause serious results. The special requirements for these mineral constituents are discussed in the following paragraphs.

98. Calcium and phosphorus.—When the supply of either calcium or phosphorus is too low in the feed, the skeleton acts as a reserve storehouse, doling out these minerals so that the life processes of the body may continue normally for a time. Under such conditions the calcium and phosphorus in the muscular tissues and other vital tissues of the body remain practically as high as in animals liberally supplied with these minerals. In a trial at the Wisconsin Station [12] by Hart, McCollum, and Humphrey a cow fed a ration deficient in calcium during 110 days gave off 5.5 lbs. more calcium in milk and excrement than was in the feed. This was about one-fourth of all the calcium in her body, including the skeleton, at the beginning of the trial.

Such withdrawal of mineral matter from the skeleton produces porosity and brittleness of bone. In certain localities where the hay and other roughages are especially low in calcium and phosphorus, farm animals are so affected by the lack of these mineral substances that their bones are broken easily and in seemingly inexplicable ways. Often this brittleness of bone is noticeable only in years when the normal absorption of calcium and phosphorus by the roots of plants is hindered by drought. Of grown animals, those carrying their young are most apt to suffer from the lack of these substances, since considerable amounts are deposited in the fetus. Growing animals whose bones are rapidly increasing in size suffer from a lack of calcium or phosphorus sooner than grown animals.

Fortunately, roughage from the legumes, such as clover and alfalfa hay, is especially rich in calcium and is also quite high in phosphorus. Previously the high value of these roughages in stock feeding has been attributed primarily to their richness in protein. Experiments carried on continuously since 1908 at the Wisconsin Station [13] by Hart, Steenbock, and Humphrey have shown clearly that the beneficial effects of leguminous roughages are also due to their richness in lime. Dry cows fed oat or wheat straw, with grain and grain by-products added to

[12] Research Bul. 5; Am. Jour. Physiol., 1909.

[13] Wis. Res. Buls. 17 and 49; Buls. 287 and 323, pp. 15-17.

make a ration balanced according to the feeding standards, have usually aborted or produced dead or weak offspring. When calcium has been added to the ration in such forms as calcium phosphate or wood ashes, the results have been greatly improved, but the calves have not been as vigorous as where alfalfa or clover hay has formed part of the roughage. Other roughages high in lime have likewise given satisfactory results, including corn stover and even timothy hay and marsh hay, which were higher in lime than is frequently the case, because they had been grown on alkaline soil. From these experiments they advise that rations for dry breeding cows contain at least 0.45 per ct. of lime (calcium oxide), and preferably even a larger amount.

In similar experiments with swine it was found that when brood sows were restricted to a ration of grain and common salt, many of the pigs produced were dead at birth, even tho the sows drank water which contained considerable lime. When 15 to 25 per ct. of alfalfa hay was added to the ration, normal living litters were produced.

These trials show in a striking manner that in forming rations the calcium content of feeds should be considered. Forage from the legumes greatly excels all other farm-grown feeds in amount of calcium. Milk and the dairy by-products, skim milk and buttermilk, are also very rich in calcium. Tho containing much less than legume hay, the legume seeds in general, and also cottonseed meal and linseed meal, are richer than the cereal grains. Straw, root crops, molasses, and the cereals and their by-products are low in calcium.

Most of the common feeds which are rich in protein are also high in phosphorus. Therefore, rations which contain sufficient protein to meet the feeding standards will usually contain plenty of phosphorus. The cereals and their protein-rich by-products are rich in phosphorus, as are also the various oil meals and cakes, the slaughter-house and fish wastes, and the leguminous roughages. On the other hand, straw, beet pulp, potatoes, and molasses are low in this mineral constituent.

Formerly it was believed that phosphorus in such organic compounds in feeds as the proteins and the phosphorus-bearing fatty substances had a higher nutritive value than phosphorus in such materials as ground bone and ground rock phosphate, which contain phosphorus in the inorganic form of phosphate of calcium. Contrary to the earlier opinions, numerous experiments [14] have shown that animals can assimilate and use these inorganic phosphates just as well as phosphorus in the organic compounds.

99. Mineral supplements.—Whenever there is any danger that the feeds given farm animals contain too little calcium or phosphorus for health and maximum production, these mineral nutrients may be supplied at little expense. Calcium alone may be furnished in the form of pre-

[14] Hart, McCollum and Fuller, Wis. Res., Bul. 1; Forbes, Ohio, Tech. Bul. 5; Burnett, Nebr. Bul. 107; Köhler, Land. Vers. Stat., 61, 1905; 65, 1907; Neumann, Jour. Landw., 41, 1893, p. 343.

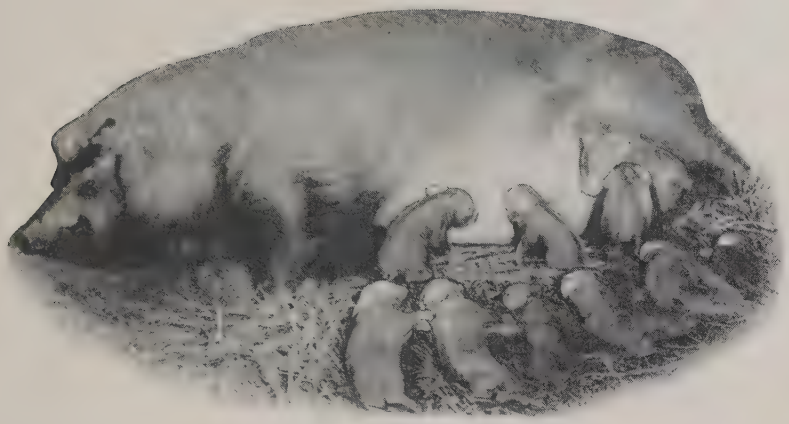
cipitated calcium carbonate, finely ground limestone, wood ashes, or chalk. Both calcium and phosphorus are supplied by steamed bone meal, bone flour, bone black, precipitated bone, or even ground rock phosphate, tho the latter is probably less soluble in the digestive tract than the other forms. When animals are allowed to help themselves to the mineral supplement, it is best to use one of the phosphates, for they are usually more palatable than the carbonates, such as ground limestone, and also they may be eaten in much greater quantity without causing any disturbance in digestion. In supplying a mineral supplement, it is a good plan to mix the supplement with the concentrates. The amounts recommended for the various classes of stock are stated in later chapters of this volume. The use of expensive proprietary mineral mixtures is unnecessary and generally uneconomical. (292)

100. Common salt.—In spite of the well-known hunger of herbivorous animals for salt, practical men have differed as to the necessity or advantage of adding it to the ration. It is now agreed, however, that salt should be supplied regularly to farm animals. It not only serves as a spice to whet the appetite and add to the palatability of many feeds, but it also stimulates the digestive glands and prevents digestive disturbances. At least for cows in milk, a supply of salt in addition to that contained in the feed is absolutely necessary for health. This was shown in experiments by Babcock and Carlyle at the Wisconsin Station [15] in which dairy cows, well fed otherwise, were given no salt for periods as long as a year. After 2 or 3 weeks, they showed abnormal appetites for salt, but their health was not usually affected for a much longer time. Finally, a complete breakdown occurred, marked by loss of appetite, lusterless eyes, rough coat, and a very rapid decline in both live weight and yield of milk. If salt was supplied recovery was rapid. In one case potassium chlorid was given instead of common salt (sodium chlorid). Recovery followed as quickly as when common salt was supplied, showing that not the lack of sodium but the lack of chlorin was responsible for the troubles.

Cows in milk and sheep need the largest amounts of salt; fattening cattle, horses, dry cows, and stock cattle require less; and pigs but little. The salt requirement will vary considerably in different localities. Soils which contain large quantities of salt doubtless produce feeds containing more salt than those poor in this ingredient; and also the water of streams and wells varies in salt content. The needs of each class of farm animals for salt are discussed in the respective chapters of Part III.

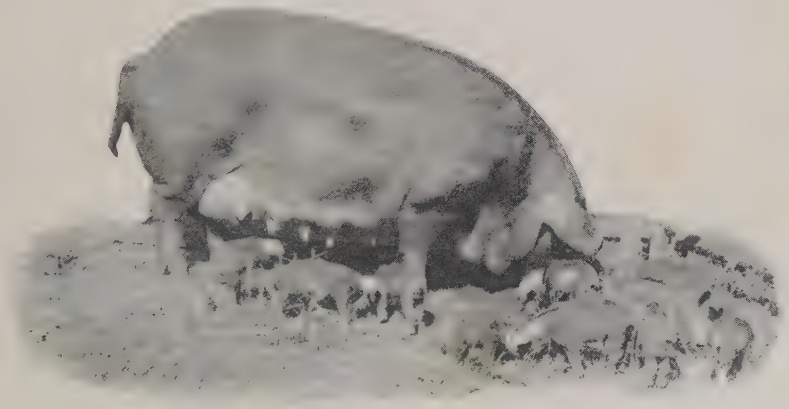
101. Iodine.—Especially in certain sections of the northwestern states, during recent years heavy losses have been experienced of new-born pigs, lambs, kids, calves, and foals, due to goitre or "hairlessness." The young so affected are born dead or weak, are frequently hairless, and commonly have enlarged necks. This is due to the thyroid gland in the neck being diseased and enlarged, just as in the case of humans suffer-

[15] Wis. Rpt. 1905.



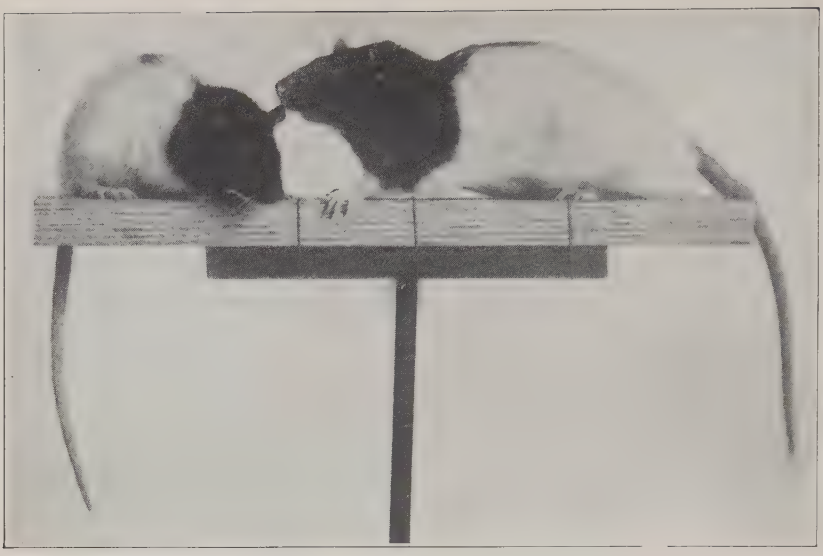
GOITRE, OR "HAIRLESSNESS," SOMETIMES CAUSES HEAVY LOSSES

Part of the pigs in this litter are hairless and dead, while others have some hair and are still alive. See Pages 68-9. (From Wisconsin Station.)



"HAIRLESSNESS" MAY BE PREVENTED BY SUPPLYING IODINE

The same sow shown in the first illustration on this page produced this thrifty litter, after she had been given iodine in the form of potassium iodide during her next gestation period. (From Wisconsin Station.)



THE FAT-SOLUBLE VITAMINE IS ESSENTIAL FOR LIFE

The vigorous, thrifty rat on the right received plenty of fat-soluble vitamine in the form of butter fat. The rat on the left, which received a so-called "butter substitute" instead of butter, is of the same age but has been stunted, due to a lack of the vitamine. (From Wisconsin Station.)

EFFECT OF A LACK OF WATER-SOLUBLE VITAMINE

The chick on the left received plenty of water-soluble vitamine, while the one on the right is stunted, due to a lack of this food essential. Practically all ordinary rations fed live stock contain plenty of this vitamine. (From Wisconsin Station.)

ing from goitre, brought about probably by a lack of iodine in the feed or a failure to absorb and use the traces of iodine usually present in the feed. Recent investigations[16] have shown that this trouble with the offspring can be overcome by administering iodine in the form of potassium iodide to the pregnant dams. Specific recommendations for the prevention of goitre in pigs, lambs, and calves are given in the respective chapters of Part III. (**917, 838, 685**)

IV. Additional Requirements of Animals

We have thus far considered in detail only the requirements of animals for crude protein, carbohydrates, fat, and mineral matter. However, just as vital as the demands for fuel and repair material, which are met by these nutrients, is the need for air, water, and vitamines. It is also necessary that the ration in its physical nature or bulkiness be adapted to the capacity of the digestive organs of the given animal.

102. Air.—While animals survive starvation for a considerable time, lack of air brings immediate death, as a supply of oxygen is required for all vital processes. Carbon dioxid, which is poisonous if present in too large amounts, is being constantly produced in the body and voided into the air. (**88**) Therefore, for animals confined to closed stables, as in winter in the northern states, an efficient ventilating system must be provided to keep the air pure. This also will prevent the stable becoming damp and wet, which is likewise injurious to stock.

It is commonly assumed that a ventilation system should be so designed that the carbon dioxid content of the stable air will not often rise above about 0.167 per ct. by volume.[17] To maintain this degree of purity there must pass into the stable every 24 hours the following amounts of outside air for each head of stock. For well-fed cows, 82,843 cu. ft.; for horses, 55,379 cu. ft.; for swine, 18,410 cu. ft.; and for sheep, 7,976 cu. ft.

Cold outside air entering the stable is warmed by the heat animals give off thru radiation and conduction. (**89**) Even disregarding the heat lost by radiation from the stable itself, if the air is kept at the above degree of purity, the heat thus produced can maintain the temperature of the stable only about 36.5° F. above that of the outside air. Therefore in zero weather to keep the stable temperature at 50° F. or above, which is considered desirable for dairy cows, the ventilation should be restricted somewhat below the amounts previously indicated.

103. Water.—Animals can live much longer without solid food than without water. An abundant supply of water is necessary for all the vital processes of the body, such as the digestion and absorption of food

[16]Welch, Mont. Bul. 119; Hart and Steenbock, Wis. Bul. 297; Kalkus, Wash. Bul. 153.

[17]King, Ventilation for Dwellings, Rural Schools and Stables; Armsby, Jour. Agr. Res., 21, 1921, pp. 343-68.

nutrients and the removal of waste from the body. As already shown, water is also an agent in regulating the body temperature, both thru the vapor given off by the lungs and the evaporation of sweat from the surface of the body. If water is withheld from an animal for some time, the processes of mastication, digestion, absorption, and assimilation are hindered; the intestines are not properly flushed, and waste matter remains too long therein; the blood thickens; and the body temperature is increased. Thru these complications death may result. Animals partially deprived of water for a long period lose their appetite for solid food, and vomiting and diarrhea may occur, the latter also often taking place when water is again supplied.

Scientists agree that farm animals should have all the water they will drink at regular intervals, for they do not take it in excess unless they are forced to live on watery foods or are given salt irregularly. The water for stock must be fresh and pure to avoid disease. All water that is drunk must be raised to the temperature of the body, thus consuming heat. Warming cold water taken into the body does not necessarily mean that more food nutrients must be burned, for as has been pointed out previously (**90**), animals produce a large amount of heat in the work of digesting food and converting the digested matter into body products or work. Due to this, many animals have an excess of body heat. Comfortably housed and well-fed steers and dairy cattle may produce more heat thru this means than is needed to warm their bodies, and the excess may go to warm the water they drink, so that no food is directly burned for that purpose. However, when animals are watered but once a day, they then drink a large amount. In winter if the water is cold this makes a sudden demand for a large amount of heat, which may exceed the amount of excess heat being produced in the body. Food must then be burned simply to warm the water, even tho thereafter an excess of heat may be produced in the body. For this reason, feed may be saved by watering animals frequently which are unduly exposed to cold and those fed scanty rations, or else by warming the water. During severe winter weather cows producing a heavy yield of milk need more water than they are apt to drink if it is supplied too cold. Especially for such animals, a system of automatic drinking buckets installed in the stable, is advantageous.

Under normal conditions animals consume a fairly uniform quantity of water for each pound of dry matter eaten. Possibly due to their laxative nature, feeds rich in crude protein—bran, linseed meal, peas, etc.—cause a greater demand for water than starchy feeds. Kellner[17a] found that for each 100 lbs. of water in the water drunk and in the food, the ox voided 46.3 lbs. in the feces, 29.2 in the urine, and 24.5 in the breath and perspiration. Water is an important regulator of the temperature of the animal body. A large amount of heat is absorbed in

[17a] Landw. Vers. Stat., 53, 1900, p. 404.

converting water into the vapor given off by the lungs and skin, and when sweat evaporates it carries much heat from the body. (89)

When entirely oxidized in the body, 100 lbs. of starch or cellulose will yield 55.5 lbs. of water and 163 lbs. of carbon dioxid, and fats over twice as much water as starch. The nitrogenous compounds yield a little less than the carbohydrates, because they are not entirely oxidized in the body. This shows that a very considerable amount of water comes to the animal body from the dry matter of the food consumed.

104. Vitamines.—Within the past few years investigators have made some of the most important discoveries in the whole field of animal nutrition. They have found that the classes of nutrients previously discussed —proteins, carbohydrates, fats, and mineral matter—are not all that is necessary to make a satisfactory ration. Just as essential as these nutrients are certain compounds called "vitamines," the composition of which is unknown. Thus far, the existence of three different vitamines has been discovered: (1) the fat-soluble vitamine; (2) the water-soluble vitamine; and (3) the antiscorbutic vitamine.

Hopkins [18] observed that when a small amount of milk was added to a ration of purified nutrients on which animals would not grow, they would then grow normally. Stepp[19] similarly found that animals well fed upon foods from which all substances of a fatty nature had been removed could not live. No better results were secured when pure true fats, such as palmitin, stearin, and olein—the most common plant and animal fats—were added to the ration. On the other hand, when certain crude fatty extracts of foods, such as butter fat, were added, the animals could be maintained satisfactorily. McCollum at the Wisconsin Station[20] and very shortly thereafter Osborne and Mendel at the Connecticut (New Haven) Station[21] showed that young animals (rats) failed to grow after 3 or 4 months on rations of purified nutrients which lacked fats. The addition of lard, commercial olive oil, or commercial cottonseed oil caused no improvement. However, when butter fat, egg fat, or kidney fat was added, the diet was made complete, and normal growth and reproduction resulted. What was lacking in the ration was therefore not fat but some substance soluble in fats and hence carried along in the butter fat and egg fat. This substance is called *the fat-soluble vitamine.* It has sometimes been called "the growth stimulant," but this term is misleading, for it is not only required for growth but is even indispensable for maintaining mature animals. It is also called "fat-soluble A" and "vitamine A."

Further investigations by McCollum, Osborne and Mendel of the Connecticut (New Haven) Station, Hart and Steenbock of the Wisconsin Station, and others have shown that the cereals are generally poor in

[18]The Analyst, 31, 1906, pp. 385-397; Jour. Physiol., 14, 1912, p. 425.
[19]Biochem. Ztschr., 22, 1909, pp. 452-460; Ztschr. Biol., 59, 1912, p. 366.
[20]Jour. Biol. Chem., 15, 1913, p. 167; 19, 1914, p. 245; 20, 1915, p. 641.
[21]Jour. Biol. Chem., 16, 1913-14, p. 423; 17, 1914, p. 401.

this vitamine.[21a] Steenbock has recently found that altho white corn is deficient in the vitamine, yellow corn contains enough for normal growth of rats. Fortunately, the green portions of plants have, so far as they have been investigated, been found to be rich in the vitamine, as are also the softer portions of beef fat, cod-liver oil, carrots, and sweet potatoes. Hemp seed and some varieties of millet seed contain fair amounts, and linseed meal, soybeans and field peas have appreciable quantities. Irish potatoes, mangels, sugar beets, and dasheens are low in this fat-soluble vitamine. Skim milk and whey contain much less than whole milk.

The discovery that the green parts of plants are rich in this vitamine, coupled with the further fact that the vitamine is not rendered inactive by drying, such as occurs in hay making, is of prime importance in feeding live stock. Because of this, farm animals consuming plenty of good roughage, such as well-cured legume hay, will undoubtedly secure enough of the vitamine. There may sometimes be danger of a deficiency with pigs reared without pasture or legume hay, and with young calves being raised on milk substitutes. Yellow corn is probably not superior to white corn for feeding dairy cows, beef cattle, horses, or sheep, if they are supplied with plenty of good roughage. As is pointed out later (**939**), it has been found superior to white corn for pigs in dry lots and receiving no other feeds rich in the fat-soluble vitamine. For pigs on pasture it was no better.

The second vitamine, which is soluble in water, and is therefore called *the water-soluble vitamine*, was discovered by Funk[22] in the study of the disease known as beri-beri. This malady, which causes general weakness and even paralysis, affects humans in districts of the Orient where the inhabitants live mainly on polished rice. When unpolished rice, carrying the germ, and part of the husk, is eaten instead, this disease does not occur. Animals affected with this disease are cured by administering the water-extract of rice germ, or of other foods rich in the water-soluble vitamine. While this vitamine is not present in the purified nutrients—proteins, starch, sugars, or fats—it is more widely distributed than the fat-soluble vitamine and in more generous amounts. An abundance has been found by McCollum, Osborne and Mendel, Hart and Steenbock, and others in most ordinary foods, such as the cereals and other seeds, milk, eggs, and the leafy portion of plants. Yeast is especially rich in the vitamine. It is not destroyed by drying or exposure to light. Therefore all ordinary rations for live stock will contain an ample supply of the water-soluble vitamine. Tho highly milled flour contains little of this vitamine, humans eating a modern varied diet undoubtedly secure

[21a]For general discussions of vitamines and extended bibliographies see: Sherman, The Vitamines, 1922; Eddy, The Vitamine Manual, 1921; and Harrow, Vitamines, Essential Food Factors, 1921.

[22]Ergeb. Physiol., 13, 1913, p. 125.

plenty of it in the other foods they eat. The water-soluble vitamine is also called "water-soluble B" and "vitamine B."

So far as our present knowledge goes, the third vitamine, *the anti-scorbutic vitamine,* which prevents scurvy, is of little or even no importance at all in the feeding of all classes of farm animals. Quite probably farm animals in general require such small amounts of this vitamine that all rations fed to them furnish ample amounts. In feeding humans, monkeys, and guinea pigs, however, this vitamine must be furnished or scurvy will result. This vitamine is supplied by fresh fruits and vegetables, milk, and fresh meat, but is low in the cereals. It is easily destroyed by prolonged cooking or drying at high temperatures.

Recent investigations suggest the existence of a fourth vitamine, *the anti-rachitic vitamine,* or the preventive of rickets. The disease called rickets, which seriously affects the bones, may be caused by a lack of calcium or phosphorus in the food or a failure of the body to assimilate these minerals. It often affects children, and growing pigs frequently suffer from it, especially in winter. Possibly *the anti-rachitic vitamine* may be the same as *the fat-soluble vitamine,* for cod-liver oil, which is exceedingly rich in the fat-soluble vitamine, cures rickets. However, other substances which are also rich in the fat-soluble vitamine are said not to be remedies for rickets. Therefore a separate vitamine may exist in cod-liver oil and certain other substances. (**919**)

Appendix Table IX indicates the relative amounts of vitamines in some of the more important feeds, as far as information is available.

105. Requirements of satisfactory rations.—The facts which have been emphasized in this chapter make it clear that for health and even life itself it is not sufficient that animals receive merely plenty of protein, carbohydrates, and fat. It is just as essential: (1) that the food protein be not only ample in amount but also of the right kind, (2) that there be an adequate supply of mineral matter, and (3) that the food contain enough of the vitamines.

If the ration lacks any of these factors, the results will be unsatisfactory, the health of the animal may be injured, and death may even result. Fortunately, with horses, cattle, and sheep fed balanced rations containing plenty of good roughage, there is little danger of trouble from any of these sources. With swine not on pasture there is much more chance of the ration being incomplete, even when it is balanced so as to supply plenty of protein. This is because swine are commonly fed chiefly on the cereal grains. These not only have proteins of unbalanced nature, but also they are low in lime and, with the exception of yellow corn, contain but little fat-soluble vitamine. Poultry also often suffer from inadequate rations. Because of the importance of these new discoveries and the wide-spread interest in them, special emphasis is given thruout this volume to all practical applications of these factors which have thus far been brought to light.

106. Feeding ruminants concentrates only.—By reason of their high ability to digest coarse roughage, ruminants are especially adapted to convert the coarse plant materials of no value for human food into useful products. Tho only under most exceptional conditions would it be profitable to feed such animals concentrates alone, the question whether they can be maintained on such feeds with no roughage is of scientific interest.

In 1874 a Mr. Miller of New York[23] reported that for several years he had maintained dry dairy cows for 8 weeks in winter in fair condition on corn meal alone. At first the cows were restless, but soon quieted down and rumination, or chewing the cud, ceased. The cows showed no signs of suffering or unrest and manifested no unusual desire for hay when it was shown them. The calves from these cows were healthy and active.

A 2-year-old steer fed for nearly 8 months only grain and water by Sanborn[24] at the Utah Station made fair gains. Furthermore, in Great Britain sheep are often fattened solely on concentrates and roots. We may therefore conclude that mature ruminants can be maintained for considerable periods on concentrates alone.

With young ruminants Nature is less yielding, for most attempts to raise calves on milk alone or milk and grain without hay or other roughage have failed, as is shown in a later chapter. (**692**)

107. Horse requires roughage.—Patterson of the Maryland Station[25] attempted to feed 2 horses on oats alone, offering from 13 to 15 lbs. to each daily. By the end of the fourth day one of the horses refused the oats entirely and drank but little water. On the seventh day the other horse would eat only a part of the grain, and by the tenth day none whatever. Evidently the horse cannot live upon concentrates alone, even oats with their straw-like hulls.

108. Roughage for pigs.—Swine have been raised with fair success on milk alone without grain or roughage in trials by McCollum and later by Hart and Steenbock at the Wisconsin Station.[26] However, when pigs are restricted to rations of concentrated feeds, such as grain and a limited amount of milk or grain with linseed meal or wheat middlings, they often become stiff and "rheumatic" and may finally become unable to walk. This condition, which resembles rickets in humans, may be prevented by adding legume hay to the ration, as is explained in Chapter XXXIII. (**918**)

109. Succulent feeds.—Numerous scientific trials and common experience on farms have abundantly demonstrated the value of adding succulent feeds to the rations of farm animals. The beneficial effects of succulence, whether supplied as pasturage, silage, soilage, or roots, are many. Just as our own appetites are stimulated by fruits and green

[23]Rpt. Am. Dairyman's Assoc., 1874.
[24]Utah Bul. 21. [25]Md. Bul. 51. [26]Unpublished data.

vegetables, succulent feeds are relishes for the animals of the farm, inducing them to consume more feed and convert it into useful products. It is reasonable to hold that such palatable feeds stimulate digestion (**56**), and it is well known that their beneficial laxative action aids greatly in keeping the digestive tract in good condition. The dairy cow gives her maximum returns when she is supplied with succulence. Such feeds tend toward rapid, sturdy growth with the young of all farm animals. Steers and sheep make rapid and economical gains on pasture, and grass-fed animals are in the best possible condition to make rapid gains when placed in the feed lot. Among the most important contributions of the experiment stations are their demonstrations of the economy of feeding silage to dairy cattle, beef cattle, and sheep and of the possibilities of cheapening the cost of producing pork thru the utilization of pasture. The merits of the various forms of succulence for the different farm animals are discussed in detail in later chapters of the book.

110. Light.—Sunlight is a most effective germicide. To prevent the contraction or spread of disease, it is therefore important that the stables of farm animals be well lighted, with the possible exception mentioned in the following. For fattening animals the quarters may be darkened somewhat, as this may tend to keep them more quiet and thus favor fattening.

It has recently been discovered that light seems to aid in preventing rickets, and it may possibly have other beneficial effects, yet unknown, on the health of animals.

111. Exercise.—For the maintenance of health exercise is essential. The only exceptions to this rule are fattening animals, soon to be marketed, which make more rapid gains if not allowed to move about too freely. Abundant exercise is of special importance with breeding animals. The exercise requirements of the various farm animals are discussed in the respective chapters of Part III.

112. Quiet and regularity.—Farm animals are creatures of habit, and once accustomed to a routine of living show unrest at any change. The feed stable or feed lot should be free from disturbance, and the administration of feed and water should be uniform in time and manner. Animals soon learn when these are to occur, and as feeding time approaches the secretions begin pouring from the various digestive glands in anticipation of the coming meal. (**55**) The system of feeding and watering and the character of the rations should be changed gradually and only for good cause. In feeding operations a changing period is often a losing period.

CHAPTER V

GROWTH AND FATTENING

I. Growth

We have seen in the preceding chapter that in maintaining mature animals but relatively little protein and mineral matter are needed to replace the small daily waste of these substances from the body. The requirements for young, growing animals are far different, for their bodies are increasing rapidly in both protein and mineral matter. Also, in the growing body and its organs considerable fat is stored, especially if the animal is well fed. Therefore, in addition to being supplied enough food to maintain its weight, the growing animal must receive additional nutrients to provide for the building of its body. Vitamines are necessary both for maintenance and for growth.

113. Requirements for growing animals.—The skin, muscles, ligaments, tendons, and internal organs of animals are almost wholly protein, as is a large part of the nervous system and the organic portion of the bones. During youth, all these parts steadily increase in size, and at the same time much mineral matter is built into the skeleton or is retained in the vital parts of the body cells. It is clear, therefore, that the rations for growing animals should contain a much larger proportion of protein and mineral matter than is needed in those for maintaining mature animals.

After growth is completed, but little storage of protein or mineral matter can take place, for the skeleton, the muscles, and the internal organs have reached full development. The muscular fibers, of which the muscles are composed, increase in number only during youth. Indeed, it is believed that the muscles of the newborn young of some animals contain as many fibers as those of the mature animals.[1] As the fibers can thicken only to a limited extent, the muscular tissues, or lean meat, of a mature animal can be increased but little compared with the great storage of fat which may occur.

If an animal is healthy but has poor muscular development, some increase in the size of the muscles can be made thru a thickening of the individual fibers produced by suitable exercise and food, as shown by the experiments of Caspari[2] and Bornstein.[3] An animal whose muscles have wasted thru sickness or starvation will rapidly repair its tissues upon a return to favorable conditions, thereby storing protein. Beyond these exceptions the only storage of protein and mineral matter which

[1]J. B. MacCallum, Johns Hopkins Hospital Bul. 90-91 (1898).

[2]Archiv. Physiol., 83, 1901, p. 535. [3]Archiv. Physiol., 83, 1901, p. 548.

EFFECT OF A LACK OF ANTI-SCORBUTIC VITAMINE

Above.—A thrifty guinea pig, which received plenty of the anti-scorbutic vitamine. Below.—A guinea pig suffering from scurvy, due to a lack of this vitamine. See Page 73. (From Wisconsin Station.)

PIGS SUFFERING FROM SEVERE CASES OF RICKETS

These pigs received a ration of white corn and skim milk, without pasture. Note the paralyzed condition. The pig on the left died within a week after the photograph was taken, while the one on the right gradually recovered when cod-liver oil was added to the ration. See Pages 73 and 607. (From Wisconsin Station.)

MILK IS THE NATURAL FOOD FOR YOUNG MAMMALS

A study of the composition of milk shows that young animals should have rations rich in protein and in mineral matter, especially calcium and phosphorus. They must also have plenty of concentrates. (From Wisconsin Station.)

RESULTS OF FEEDING GROWING PIGS A DEFICIENT RATION

These pigs were raised at the Wisconsin Station on grain and grain by-products, without pasture or other feed. They became stunted and finally developed the severe paralysis shown here. The proteins in such a ration are unbalanced in composition; there is a deficiency of mineral matter, especially calcium; and there may be a lack of vitamines. (From Hart, Wisconsin Station.)

can occur in mature animals is in the growth of the nitrogenous hair and hoofs, and in the small amount of protein and mineral matter in the fatty tissues.

We have seen that maintenance rations may consist chiefly of roughage, which furnishes little net energy. On the other hand, for thrifty growth, the ration must be more concentrated (that is, must furnish more net energy) to provide for the energy stored in the growing tissues of the body in the form of protein and fat. Furthermore, the rations for growing animals must contain adequate supplies of vitamines, as discussed later in this chapter. (120)

114. Utilization of food in youth.—It is a well known fact that young animals make much more rapid gains, considering their size, than those made by mature animals, even when fattening. For example, an unweaned calf may make gains of 2 to 3 lbs. daily for each 100 lbs. of body weight, while a daily gain of 0.3 to 0.4 lb. per 100 lbs. of body weight is large for the mature fattening ox.

As we shall see later, mature animals can store much fat in their bodies, but can make no material gains in protein and mineral matter. On the other hand, young animals can retain and build into their protein tissues and skeleton a large part of the protein and mineral matter in their rations. For instance, in respiration studies with a calf 2 to 3 weeks old, Soxhlet[4] found a storage in the body of 72.6 per ct. of the protein, 96.6 per ct. of the lime, and 72.6 per ct. of the phosphorus fed in the milk. Weiske[5] found that even when 5 months old, lambs stored 22 per ct. of all the protein digested from their food. While a calf 8 days old will store nearly 0.40 lb. of protein per 100 lbs. body weight, the rate of storage of protein rapidly falls. At a month of age it will store only about 0.28 lb. per 100 lbs. body weight; at 2 months, about 0.16 lb.; at 6 months, about 0.08 lb. and at 10 months, only about 0.05 lb.[6] These data show that the quantity of protein built up into body tissues steadily diminishes as maturity approaches.

Numerous practical feeding trials reviewed in Part III of this book show that young animals require considerably less feed for 100 lbs. of gain in body weight than those which are older. Because of this, young animals have a marked economic superiority in the production of meat. There are several reasons for the more rapid gains and the more economical meat production of young animals. Their gains are much more watery than those of more mature animals, and also contain more protein and much less fat, which has a much higher heat value than protein. Much more net energy is therefore required to make a pound of gain on a mature fattening animal than on one which is young and growing. Furthermore, the food consumed by young animals is ordinarily lower in fiber, and hence more digestible and

[4] Ber. landw. chem. Vers. Stat., Wien., 1878, p. 101.

[5] Landw. Jahrb., 9, 1880, p. 205.

[6] Armsby, Nutrition of Farm Animals, pp. 376-7.

higher in net energy than that eaten by older animals. In addition, since young animals consume much more feed in proportion to live weight, they have left for building into body tissues a much larger part of their feed after the maintenance requirements of the body have been met. These factors account fully for the greater economic efficiency of younger animals. Contrary to common popular opinion, there is no evidence that a young animal makes any better percentage utilization of the net energy supplied in the feed than an older one.[7]

From the practical standpoint, it is of prime importance in feeding animals for meat production to take advantage of the great stimulus to growth when animals are young. Growing animals should therefore always be fed rations rich enough in protein and mineral matter to permit rapid and economical growth of body tissues and skeleton.

115. Milk the natural food for young mammals.—Since milk is Nature's food for the young of all mammals, it is reasonable to hold that it contains all the nutrients necessary to sustain the life of the young and that these are arranged in proper proportion. A study of the composition of milk, as given in the following table,[8] will therefore aid in showing the requirements for growth:

Composition of normal milk and of colostrum milk

	Water Per ct.	Mineral matter Per ct.	Protein Per ct.	Sugar Per ct.	Fat Per ct.
Cow, normal milk.....	87.2	0.7	3.5	4.9	3.7
Ewe, normal milk.....	80.8	0.9	6.5	4.9	6.9
Sow, normal milk.....	81.0	1.0	5.9	5.4	6.7
Cow, colostrum milk.....	74.5	1.6	17.6	2.7	3.6
Ewe, colostrum milk.....	61.8	1.0	17.1	3.5	16.1
Sow, colostrum milk.....	70.1	0.9	15.6	3.8	9.5

The table shows that milk contains an abundant supply of protein compared with the amount of other nutrients. While the nutritive ratio of dent corn is 1:10.4, the nutritive ratio of normal cow's milk is 1:3.9. Ewe's milk and sow's milk are even richer in protein than is cow's milk. Milk is also much richer in mineral matter than are the cereal grains. While only 1.5 per ct. of the dry matter of corn and 3.5 per ct. of the dry matter of oats is mineral matter, the dry matter of cow's milk contains 5.5 per ct. The supply of lime and phosphoric acid, needed in large amounts in the growing skeleton, is especially liberal, these two constituents forming about half the total mineral matter. Milk also contains a liberal supply of the fat-soluble vitamine and of the water-soluble vitamine, both of which are necessary for animals. (**104, 120**) The sugar and fat in milk furnish energy in concentrated form and also supply nutrients for the formation of the fatty tissues of the body.

These studies of the composition of milk teach that after weaning, young animals should be given feeds similar to milk in composition:

[7]Armsby, Nutrition of Farm Animals, pp. 390-396.

[8]Partly from König, Chem. Nahrungs- und Genussmittel, Vol. I, 1903.

i. e., rich in protein and mineral matter. For this reason, such feeds as hay from clover, alfalfa, or other legumes, and protein-rich concentrates, as wheat bran and linseed meal, are of high value for young animals.

The second part of the table shows that colostrum, which is the first milk yielded by the mother for her young, is much richer in protein and often higher in ash than normal milk. The high protein content is due to its richness in globulin and albumin, which cause such milk to clot on heating. Colostrum is laxative and highly important for cleansing the alimentary tract of accumulated fecal matter. Recent investigations show that colostrum apparently immunizes the new-born temporarily against certain diseases. During the week following birth the composition of the milk gradually changes to normal.

116. Relation between composition of milk and rate of growth.—In their analyses of different kinds of milk Bunge, Proescher, and Abderhalden[9] noted the striking relationship, shown in the table, between the rate at which different species of animals grow and the amount of mineral matter and protein contained in the milk:

Influence on growth of amount of protein and mineral matter in milk

Species	Time required to double weight Days	Protein in milk Per ct.	Lime in milk Per ct.	Phosphoric acid in milk Per ct.	Total ash in milk Per ct.
Human	180	1.6	0.03	0.05	0.20
Horse	60	2.0	0.12	0.13	0.40
Cow	47	3.5	0.16	0.20	0.70
Sheep	15	4.9	0.25	0.29	0.84
Pig	14*	5.2	0.25	0.31	0.80
Dog	9	7.4	0.45	0.51	1.33
Rabbit	6	14.4	0.89	0.99	2.50

* According to more recent data the young pig may double its weight in 8 or 10 days.

The infant, which requires about 180 days to double its weight, receives a milk containing but 1.6 per ct. protein, 0.03 per ct. lime, 0.05 per ct. phosphoric acid, and 0.20 per ct. total ash, or mineral matter. The shorter the time required by the new-born young of different species to double in weight the larger is the content of protein and of mineral matter, especially lime and phosphoric acid. It thus appears that there has been provided for the young of each species milk of the composition needed for the development characteristic of that species. These studies emphasize the necessity of maintaining a liberal supply of protein and mineral matter in the ration of young animals as the mother's milk is replaced by other feeds during their early life.

117. Rich and poor milk for young animals.—Beach of the Connecticut (Storrs) Station[10] fed calves, pigs, and lambs on skimmed milk, ordinary milk containing from 3 to 3.5 per ct. fat, and rich milk containing from 5.1 to 5.7 per ct. of fat. The lambs also received a small quantity of hay. Calves fed rich milk required 1.18 lbs. milk solids, including fat, to produce 1 lb. of gain, while others fed milk low in fat required only 1.03 lbs. The same results were secured with lambs and pigs.

[9] Abderhalden, Ztschr. physiol. Chem., 27, 1899, p. 594.

[10] Conn. (Storrs) Bul. 31.

In every case milk rich in fat was less valuable per pound of dry matter, fat included, than milk poor in fat, or even skim milk. Beach reports that the pigs fed rich milk lost their appetites and were attacked by diarrhea, finally not eating enough to sustain life, while those fed skim milk or milk low in fat, throve. It should always be borne in mind, however, that skim milk is low in the fat-soluble vitamine. (**104**)

In Europe studies on infant feeding show that cow's milk rich in fat tends to produce intestinal disturbances and is not so well adapted to the needs of the human infant as poorer milk. The following explanation of this harmful effect of excess of fat in the food of infants has been offered: The general capacity of an animal for the absorption of fat is strictly confined within narrow limits, and consequently any excess is not absorbed but remains in the intestines. There it is converted into soaps, which are formed by the combination of the fatty acids with such alkalies as lime, soda, and potash. The soaps are excreted from the body in the feces, bringing about a heavy loss of these alkalies. If this loss is long continued, it results in disturbed nutrition. On an exclusive diet of milk containing about 3.5 per ct. fat, the supply of alkaline bases is only sufficient for normal development. Milk rich in fat does not contain proportionally more of the alkaline bases, for man has bred and selected cows only to meet the demands for more milk and for that which is rich in fat. The eagerness with which calves sometimes eat mortar, chalk, and other lime-containing substances points to the milk being deficient in this respect. In such cases ground limestone or some other form of lime should be supplied.[11] (**685**)

118. Protein requirements for growth.—As has been shown (**11**), the individual proteins differ markedly in the amount of the various amino acids they contain, and in some proteins certain amino acids are entirely absent. Scientists believe that animals can construct in their bodies from other nutrients but a very few of the different amino acids, and possibly only the simplest one of all, called glycocoll. In the formation of the protein tissues of the body all the various individual amino acids are required, for the body proteins contain some of each of these building stones. Hence for normal growth the protein in the food must supply all of the necessary amino acids. The following illustration will show the conditions the body may meet in forming body proteins from the mixture of amino acids resulting from the digestion of the food protein: Suppose we are building a brick wall in a certain pattern which requires that 1 brick in 10 have a green end. If we are using as our source of material a pile of bricks resulting from the tearing down of another wall, in which only 1 brick in 50 had a green end, it is evident that we will soon have to stop building, tho having many perfect bricks left, because none has the green end required for the pattern.

Some proteins, as the principal ones of wheat, yield on digestion as much as 40 per ct. of a certain single amino acid, which forms only 14

[11]Ernähr. landw. Nutztiere, 1907, p. 461.

per ct. of the animal proteins. With wheat proteins as the sole source of amino acids for growth, obviously a considerable part will be wasted. There are certain proteins which entirely lack some of the essential amino acids and so will produce no growth. However, when the missing amino acids are fed to supplement such a deficient or imperfect protein, the animal will then be able to continue growth.

The various incomplete proteins do not all lack the same amino acids. Hence, when two incomplete proteins are combined, one may supplement the deficiencies of the other and better growth be made than on either alone. To study this problem, young growing pigs were fed by McCollum and by Hart and Steenbock at the Wisconsin Station[12] on many rations in which the protein was supplied by a single feed or by two or more feeds. When fed only corn, wheat, or oats, the pigs retained in their bodies for growth only 23 to 28 per ct. of the protein in their feed. The protein of linseed meal was of even poorer quality, only 17 per ct. being stored. However, with skim milk 66 per ct. of the protein was stored in the body. Milk casein was nearly as efficient, 51 per ct. being retained. A mixture of one-third each of corn, wheat, and oats was only a trifle better than any one of the cereals alone. On the other hand, when a mixture of three-fourths corn and one-fourth linseed meal was fed, 37 per ct. of the protein was stored, considerably better than with either feed alone. Of the feeds tested, skim milk was the most efficient supplement to the cereals. Pigs fed 1.3 lbs. of skim milk with each pound of corn, stored about 62 per ct. of the protein in their feed. On corn and tankage or on barley and tankage about 40 per ct. of the protein was stored, but on corn and alfalfa hay only 32 per ct. On corn, gluten feed, and alfalfa hay only 28 per ct. was retained, while 39 per ct. was retained on corn, alfalfa hay, and whey, and 41 per ct. on corn, alfalfa hay, and skim milk.

These results show that the proteins from the cereals are deficient in the same amino acids and do not supplement each other, while the milk proteins supplement the cereal proteins most excellently. Tankage is a considerably more efficient supplement to the cereals than alfalfa hay or linseed meal.

In feeding trials with pigs Morrison and Bohstedt have secured similar results at the Wisconsin Station.[13] Pigs weighing 129 lbs. made average daily gains of 2.10 lbs. on barley and skim milk, and 1.95 lbs. on barley and tankage, while on barley and linseed meal the daily gain was only 1.22 lbs., and on barley and middlings only 1.27 lbs. Tho whey contains but 0.8 lb. protein per 100 lbs., this small amount was found to be surprisingly efficient in supplementing barley, pigs fed only barley and whey gaining 2.53 lbs. per head daily.

In another trial pigs averaging 147 lbs. at the start gained only 1.48 lbs. per head daily on barley and middlings, while a lot fed barley and

[12]Jour. Biol. Chem., 19, 1914, p. 323; 38, 1919, p. 267; unpublished data.

[13]Wis. Buls. 319, pp. 70-71; 323, pp. 8-10.

tankage in such proportions as to provide the same nutritive ratio gained 1.75 lbs., and a lot fed barley and skim milk, 1.71 lbs. A lot fed barley and whey made still better gains, 1.95 lbs. per head daily, tho receiving a considerably wider nutritive ratio. With younger pigs more protein is needed than is supplied by whey and either barley or corn, and hence in another trial younger pigs made considerably more rapid gains when fed some protein-rich feed, such as tankage or linseed meal, in addition to grain and whey.

These trials show clearly that in feeding growing animals not only must an abundance of protein be supplied but also that it must be of the right quality. In time further studies along these lines will undoubtedly reveal the supplementing relationships of the many feeding stuffs and make possible the more efficient compounding of rations. The methods of determining the amounts of the individual amino acids furnished by different feeds are not sufficiently perfected as yet to enable scientists to ascertain by chemical analysis alone the definite value of the proteins from various sources. Hence, further knowledge concerning the value of the proteins furnished by individual feeding stuffs and by combinations of feeds must come thru actual feeding tests. The chapters of Part III show, so far as data are available, the combinations of feeds which have been most successfully used for various classes of animals.

119. Mineral matter required for growth.—It has already been shown that the young animal, growing rapidly in skeleton and tissues, needs a liberal supply of mineral matter, especially calcium (lime) and phosphorus. (113) The amounts supplied in the feeds must always be larger than the quantity actually stored in the body, in order to cover the continuous excretion thereof from the body which occurs even in case of a deficient supply.

The injurious effects of a lack of mineral matter are shown in a trial by Hart, McCollum, and Fuller at the Wisconsin Station[14] in which one lot of 47-lb. pigs was fed wheat bran from which most of the phosphorus had been removed by washing, together with wheat gluten and rice, both of which feeds are extremely poor in mineral matter. Other lots were fed the same ration plus ground rock phosphate or bone ash, which supplied ample calcium and phosphorus. For a considerable period all the pigs throve fairly well, but as time went on those fed the ration poor in mineral matter fell behind the others. They had no appetite and disliked to stand up; later they lost control of their hind quarters and had to be carried to the trough at feeding time. When the pigs were slaughtered, it was found that those fed insufficient phosphorus had light, weak bones, while those receiving ground rock phosphate or bone ash had strong, heavy ones.

At present there is little data regarding the minimum amounts of lime and phosphorus which will permit normal development of growing animals. From the available data Kellner[15] concludes that the ration

[14] Wis. Res. Bul. 1. [15] Ernähr. landw. Nutztiere, 1907, pp. 472, 476, 478.

for growing animals should contain 3 times as much of these mineral constituents as the animals are storing daily in their bodies. On this basis he recommends that during the first year calves receive at least 40 to 60 grams of lime and phosphoric acid per head daily; pigs, 12 grams each of lime and phosphoric acid per head daily; and lambs, at least 10 grams of lime and 11 grams of phosphoric acid daily for each 100 lbs. live weight.

Since most of the common feeding stuffs which are rich in protein are also high in phosphorus, probably the phosphorus supply will be ample when rations are fed which are balanced according to the usual feeding standards.[16] The calcium supply for calves and lambs will usually be ample when hay and the cereals constitute the greater part of the ration. Deficiencies will occur only in districts where the roughages are unusually low in lime, or when large amounts of such roughages as wheat and barley straw or timothy hay, which are low in lime, are fed. Where pigs are fed exclusively on cereal grains, especially on corn, the lime supply will usually be deficient. As has been shown (**99–100**), where lime alone is deficient it may be supplied in legume hay, which is rich in lime, or in the form of chalk or ground limestone. If phosphorus alone, or both lime and phosphorus are lacking, these may be supplied in the form of ground bone or bone ash or else in ground rock phosphate.

120. Vitamines required for growth.—In the discussion of vitamines in the preceding chapter (**104**), it has been pointed out that it is just as necessary that the rations of animals contain sufficient of these substances as it is that they contain adequate supplies of protein and mineral matter. Suckling animals will suffer from no lack of the fat-soluble vitamine, since whole milk is rich in it. Also, fortunately, as has been pointed out, good quality roughages are apparently in general rich in this vitamine. Therefore, when foals, calves, and lambs are old enough to eat considerable roughage they will undoubtedly secure plenty of this vitamine. In raising young pigs without forage crops and in raising calves on milk substitutes there apparently is most apt to be a lack of the fat-soluble vitamine. As has been previously stated, the rations ordinarily fed farm animals contain plenty of the water-soluble vitamine. Tho our knowledge concerning the vitamines is as yet fragmentary, many practical bearings on stock feeding have already been discovered. These are emphasized in later chapters.

121. Requirements for pregnant animals.—In considering the feeding of young animals it is important to remember that the influence of the feeder begins before the young are born, for the nutrition of the mother during pregnancy profoundly influences the growth of the fetus and hence the vigor and health of the offspring at birth. To supply the protein and mineral matter, especially lime and phosphorus, needed for the development of the body tissues and skeleton of the fetus, the ration of the mother should contain a larger supply of nutrients than

[16] Hart, Steenbock, and Fuller, Wis. Res. Bul. 30.

would be required for her maintenance. The serious results which may follow from feeding pregnant animals a ration deficient in lime have been mentioned in a preceding paragraph. (98)

Based on data from Eckles and P. F. Trowbridge[17] of the Missouri Station, the body of an 80-lb. newborn calf contains about 14.0 lbs. of protein, 2.8 lbs. mineral matter, and 2.5 lbs. fat,—an amount of protein and mineral matter that would be contained in 400 lbs. of milk of average composition.

In the case of an immature female, developing her own tissues as well as those of the fetus, a liberal supply of these nutrients is especially important. Fortunately, the mother is able to protect the offspring to a certain extent against temporary or small deficiencies in her food by drawing upon her own skeleton for the lime and phosphorus and her muscular tissues for the protein necessary to the growing body of the fetus. Such maternal protection is, however, at the expense of her own body. The requirements for the various farm animals when pregnant and the feeds best suited for their maintenance are discussed in the respective chapters of Part III.

II. Fattening

122. The object of fattening.—It is well known that the accumulation of fatty tissue, as such, is of secondary importance in fattening, the main object being to improve the quality of the lean meat itself. To some extent during growth, and especially during fattening, there is a deposition of fat in the lean-meat tissue. A small portion of this may be deposited within the muscular fibers themselves, but a much larger part is stored between the bundles of fibers, constituting the so-called "marbling" of meat. This deposition of fat adds to the tenderness, juiciness, flavor, and digestibility of the meat, besides increasing its nutritive value. There is also an increase in the soluble protein and in other extractives of the muscles, resulting in a further betterment of the quality of the meat as an additional advantage from fattening.

123. Increase during fattening.—The changes in the composition of the bodies of farm animals during fattening were extensively studied by Lawes and Gilbert of the Rothamsted Station[18] from analyses of the entire bodies of oxen, sheep, and pigs slaughtered at different stages of fattening. They give data from which the following table is derived:

Percentage composition of the increase of fattening animals

Animal	Protein Per ct.	Fat Per ct.	Mineral matter Per ct.	Total dry substance Per ct.	Water Per ct.
Ox	7.7	66.2	1.5	75.4	24.6
Sheep	7.1	70.4	2.3	79.9	20.1
Pig	6.4	71.5	0.1	78.0	22.0

[17] Information to the authors.

[18] Jour. Roy. Agr. Soc., 1860.

In most cases the animals had not entirely finished their growth when the tests began. The table shows that in 100 lbs. of live-weight gain made by the fattening ox, 7.7 lbs. was lean-meat tissue, 66.2 fat, 1.5 mineral matter, and 24.6 water. The sheep resembles the ox in character of increase during fattening, but stores more mineral matter, due to the growth of wool. The fattening pig stores little mineral matter. These studies, as well as other investigations, show that the fattening of mature animals is what the term implies—the laying on of fat—with but relatively little storage of protein.

Animals which are fattened while still growing will gain not only in fatty tissue, but also in lean meat. This is shown by the experiments of Waters, Mumford, and P. F. Trowbridge,[19] who analyzed the entire bodies of steers killed at various stages of fattening at the Missouri Station. The following table shows the composition of the carcass of a 748-lb. steer in thrifty growing condition and the composition of the gains made by other steers during fattening:

Composition of unfattened steer and gains during fattening

	Water Per ct.	Fat Per ct.	Protein Per ct.	Ash Per ct.
Carcass of unfattened steer.....	56.4	18.6	18.8	5.7
First 500 lbs. of gain.....	37.6	48.6	11.9	2.0
Second 500 lbs. of gain.....	17.8	75.6	5.2	1.5
Total 1,000 lbs. of gain.....	27.7	62.1	8.5	1.7

While the carcass of the steer killed before fattening was over half water, the first 500 lbs. of gain contained only 37.6 per ct. water and the second 500 lbs. but 17.8 per ct. The first half of the gain was 48.6 per ct. fat and 11.9 per ct. protein, showing marked increase in lean meat. In the last half of the gain 75.6 per ct. was fat and only 5.2 per ct. protein. The storage of ash was likewise less in the last 500 lbs. of gain. Thus, as a partly mature animal fattens it progressively makes less growth in lean meat and skeleton, and a larger part of the gain is fat. This fact is of much practical importance in finishing meat animals for the market, for it is the primary reason why the feed cost of 1 lb. of gain increases rapidly after an animal has become fairly well fleshed. The fat animal also requires a greater proportion of its feed for maintenance than one which is not yet well fleshed, on account of two different factors. First, the maintenance requirement of a fat animal per 1,000 lbs. live weight is higher than for a thinner one; and second, the fat animal eats less feed per 1,000 lbs. live weight, consequently having less nutrients left for meat production after the maintenance requirements have been met.

124. Composition of steers of different ages.—For several years Haecker of the Minnesota Station[20] conducted extensive investigations on the food requirements of steers of different ages, in which he had analyzed the entire carcasses of many animals. The following table shows the

[19]Information to the authors. See also Mo. Res. Bul. 30. [20]Minn. Bul. 193.

average composition of steers slaughtered at various stages, from birth up to a weight of 1,500 lbs., in these experiments:

*Average composition of steers at various stages**

Normal weight	No. of steers	Water	Dry matter	Protein	Fat	Ash
Lbs.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
100	5	71.84	28.16	19.89	4.00	4.26
200	4	70.43	29.57	19.14	6.01	4.42
300	4	65.72	34.26	18.77	11.19	4.30
400	5	65.79	34.21	19.31	10.56	4.34
500	5	62.90	37.10	19.15	13.73	4.22
600	3	61.20	38.80	19.40	15.04	4.36
700	4	60.35	39.65	18.60	16.58	4.48
800	3	58.44	41.56	18.80	18.52	4.24
900	3	54.10	45.90	17.66	24.08	4.16
1,000	4	52.03	47.97	17.11	26.91	3.95
1,100	3	47.77	52.23	16.38	32.03	3.82
1,200	3	47.96	52.04	16.02	32.32	3.70
1,300	2	47.93	52.07	15.79	32.50	3.78
1,400	1	47.76	52.24	16.15	32.58	3.51
1,500	1	43.48	56.52	15.72	37.59	3.21

*Not including contents of the digestive tract.

The table shows that the percentage of water steadily decreases as the animal matures, falling from 71 per ct. in the calves to 43 per ct. in the 1,500-lb. steer. The percentage of fat increases rapidly during the growth and fattening of the animal, increasing from 4.0 per ct. soon after birth to over 37 per ct. in the 1,500-lb. steer. The protein and ash show less change than the water and fat, but decrease percentagely as the animals increase in weight. Haecker states that the storage of protein by the animal, which is rapid in early life, shows a marked slowing up when the animal reaches a weight of about 800 lbs. On the other hand, the gain in fat is most rapid after the steer reaches a weight of 600 lbs.

125. Origin of body fat.—The source of the fat which animals store in their bodies has been the subject of much controversy. Modern authorities agree that the body fat of animals may originate either from the fat or carbohydrates of the food. Scientists still disagree somewhat upon the possibility of animal fat being formed thru the decomposition of protein, but the preponderance of evidence favors such formation, as is shown later.

126. Body fat from food fat.—Many experiments have conclusively shown that the fat in food which has been acted on by the digestive fluids in the intestines, may be directly stored in the body tissues when supplied in large quantity.

Hofmann[21] allowed a dog to starve until its weight had decreased from 26.5 to 16 kilograms and the supply of fat in its body had practically disappeared, as shown by the increased decomposition of the protein tissues at that time. For 5 days this dog was fed large quantities of

[21] Ztschr. Biol., 8, 1872, p. 153.

fat and only a little fat-free meat, during which time it gained 4.2 kgms. in weight. When slaughtered its body contained 1,353 grams of fat, only 131 of which could possibly have come from the protein fed. Hence much of the fat formed during this time must have come from the fat of the food.

Henriques and Hansen[22] fed 2 three-months-old pigs barley meal together with oil. The first pig received linseed and the second cocoanut oil. Samples of the body fat were removed from the back of each pig thru incisions, and analyzed. The fat which had formed during the feeding resembled in odor, consistency, and composition the vegetable fat which had been fed. Later, when the feeds were reversed the body fat then formed showed a corresponding change in properties.

All the digested fat taken into the body of the animal beyond that required for maintenance cannot, however, be deposited as body fat, since considerable losses always occur thru the energy expended in digestion and metabolism.

The amount of body fat which can be formed by farm animals from 100 lbs. of digestible fat in the food consumed varies from 64.4 lbs. in the case of pure fats to 47.4 lbs. in the fats of roughages.

127. Fat from carbohydrates.—Scientists agree that the fat in the body of animals can be formed from carbohydrates. As early as 1842 Liebig maintained that animal fat was formed mainly from the carbohydrates, tho it might also originate from the protein of the food. The extensive experiments of Lawes and Gilbert of the Rothamsted Station,[23] conducted from 1848-1853 with more than 400 animals, clearly showed that much more fat was stored than could be derived from the fatty matter and protein of the food.

Soxhlet[24] analyzed the body of one full-grown pig and fed another pig of the same weight a ration of rice and meat extract, both being almost free from fat, for 82 days. The second pig was then killed and its body analyzed. Assuming that the bodies of both pigs were of the same composition when the first was killed, it was found that the second pig stored 22,180 grams of fat in its body during the trial. Only 2,828 grams of this could have come from the protein and the fat in the feed, leaving 19,352 grams of fat as the minimum which must have been formed from the carbohydrates in the food. Hence at least 87 per ct. of the fat formed by this pig during the trial was derived from the carbohydrates in the food.

The formation of fat by ruminants from the carbohydrates was first demonstrated by Kühn[25] with the aid of a respiration apparatus. Oxen were fed for long periods on meadow hay and starch, which provided a ration low in protein and fat. Even if all the carbon that was con-

[22] Centbl. Agr. Chem., 29, 1900, p. 529.
[23] Jour. Roy. Agr. Soc., VI, Pt. 1, 1895.
[24] Jahresber. Agr. Chem., 1881, p. 434.
[25] Landw. Vers. Stat., 44, 1894, pp. 1-581.

tained in the protein and fat which was digested had gone to form fat in the body, there still remained a large amount of deposited fat which could only have come from the carbohydrates of the food. These conclusions were confirmed in later experiments by Kellner,[26] also with oxen. In these later trials it was shown that 100 lbs. of digested starch or digested fiber yielded about 24.8 lbs., and 100 lbs. of digested cane sugar only 18.8 lbs., of body fat.

Tho no experiments have yet been carried on to show that body fat may be formed from pure pentosans, it is certain that these carbohydrates may aid in its formation. Kellner[27] fed oxen straw in which pentosans furnished 33 per ct. of the energy. The large deposits of fat which followed must have come in part from the pentosans of the food.

128. Fat from protein.—When a liberal protein diet supplies the animal with more energy than is necessary for its maintenance, not only may a part of the excess protein be deposited in the body as flesh, but the non-nitrogenous portion resulting from the cleavage of protein may be converted into either body fat or glycogen. Since body fat may be derived from the carbohydrates, and since glucose and glycogen may be formed from the proteins, it is reasonable to hold that body fat may be formed from the protein of the food. Demonstration of the direct formation of body fat from food protein is difficult, as it is almost impossible to induce animals to consume any large quantity of pure protein food. The consumption of protein must be relatively large to maintain the nitrogen equilibrium of the body, and so usually but a small excess available for the formation of fat remains above body requirements.

Investigations by Cramer[28] with cats, and by Voit[29] and Gruber[30] with dogs which were fed large amounts of lean meat, show that the protein it contained must have been the source of the fat which was stored in their bodies during the trials.

Herbivora—the ox, horse, sheep, etc.—cannot be fed exclusively on protein, since such feeding causes intestinal disorders. Kellner,[31] experimenting with steers, added wheat gluten, which is principally composed of vegetable proteins, to a ration which was already causing a considerable deposition of fat. The feeding of 100 lbs. of protein caused the deposition of 23.5 lbs. fat in addition to the fat due to the basal ration.

129. The ration for fattening.—Since the fattening of mature animals consists mainly in the storage of fat, there is no demand for a large supply of food protein. While the Wolff-Lehmann standards (Appendix Table IV) advise nutritive ratios of 1:5.4 to 1:6.5 for mature fattening

[26] Land. Vers. Stat., 53, 1900, pp. 1-450.
[27] Landw. Vers. Stat., 53, 1900, pp. 1-450.
[28] Ztschr. Biol., 38, 1899, p. 307.
[29] Jahresber. Tier-Chem., 22, 1892, p. 34.
[30] Ztschr. Biol., 42, 1901, p. 407.
[31] Landw. Vers. Stat., 53, 1900, p. 452.

cattle, 1:4.5 to 1:5.4 for fattening sheep, and 1:5.9 to 1:7.0 for fattening swine, numerous experiments have shown that mature animals of all classes can be successfully fattened on much less crude protein.

It has been found that mature fattening animals may make satisfactory gains where the nutritive ratio is as wide as 1:16.[32] However, as shown previously (84), supplying as little protein as this is not usually economical, because it decreases the digestibility of the ration. Kellner accordingly advised that for mature fattening cattle the nutritive ratio should never be wider than 1:10 or 1:12.

On the other hand, in regions where alfalfa hay, cottonseed meal, or other nitrogenous feeds are abundant and low in price compared with those rich in carbohydrates it may be most profitable to feed a much narrower ration, even to mature fattening animals. (750) Those in thin flesh should at first be liberally supplied with protein in order that their muscular tissues may develop. For such animals Kellner held that the nutritive ratio should be about 1:6, with from 12 to 15 lbs. of digestible nutrients daily per 1,000 lbs. of live weight.

Owing to the greater economy of gains by young animals, in this country the larger part of our meat-producing animals are fattened and marketed before maturity. Such animals are adding not only fat, but also considerable lean meat to their bodies as they fatten, and therefore require a more liberal supply of protein than mature animals. Skinner, Cochel, and King[33] in extensive trials at the Indiana Station have found that 2-year-old steers make larger gains and require less feed per 100 lbs. gain when fed rations with a nutritive ratio of 1:7 to 1:7.8 than when the ration has a wider nutritive ratio. For fattening lambs rations having an average nutritive ratio of 1:6.8 proved better than when the nutritive ratio was 1:8.8. The results of these trials and other investigations have been taken into consideration in the recommendations given in the Morrison feeding standards. (Appendix Table V.)

It is important to bear in mind that since protein-rich feeds are usually high in price, the most profitable ration may not be the one producing the largest gains, as the ration containing an abundance of protein may be considerably more expensive. (197) Rations for fattening each kind and age of animals are discussed in detail in Part III.

130. Factors influencing fattening.—The deposition of fat in an animal depends primarily upon the quantity of food consumed in excess of maintenance and growth requirements. Fattening may take place at any age, tho the tendency of young animals to grow greatly reduces the proportion of food usually available for fattening. Supplying an abundance of feeds that are palatable, concentrated, and largely digestible tends to rapid fattening because a large surplus of nutrients then remains after supplying the body needs, which surplus may go to form fat.

[32] Ernähr. landw. Nutztiere, 1907, pp. 418–420.
[33] Ind. Buls. 153, 162, 167, 168, 178, 179.

The disposition of an animal to fatten depends upon breed and temperament. While a wild animal, nervous and active, can be fattened only with extreme difficulty, domesticated animals are more quiet and usually fatten readily. The restless animal is rarely a good feeder, while the quiet one, which is inclined to "eat and lie down," will show superior gains. This is not due to difference in digestive or assimilative powers, but rather to the fact that the quiet animal has, from a given amount of food, a greater surplus of nutrients available for fat building. Fattening animals must not be allowed to exercise too much as this wastes nutrients which they might store in their bodies.

III. Studies on Growth and Fattening

131. Comparative economy of animal production.—The economy with which the various classes of farm animals produce human food is discussed in detail in the respective chapters of Part III, but it will be interesting to compare directly in the following paragraphs the economy of each class of animals with the others.

Cooper and Spillman of the United States Department of Agriculture[34] have computed the following instructive estimates of the amounts of human food produced from an acre of crops fed to live stock and also from an acre of various crops consumed directly for human food. In each instance the pounds of digestible protein and the therms of energy furnished by an acre are shown. The production of live stock per acre was arrived at by assuming that the land was devoted to crops suitable for feeding the kind of animal under consideration and in the proper proportion to make a well balanced ration. For instance, in the case of hogs, four-fifths of the acre was in corn and one-fourth in clover, and it was estimated that an acre used in this manner would produce 350 pounds of live weight increase in hogs. In some instances in order to make an efficient ration, it was assumed that a part of the product of the acre was exchanged for a high-protein feed not produced on the farm, such as cottonseed meal.

The estimates given for the various farm animals are for merely the edible human food after all waste in the carcass and in slaughtering has been deducted. The figures for corn, wheat, and soybeans are for the entire seeds and not for the milled product, such as corn meal and wheat flour. The estimates for rice are for polished rice and those for oats for the hulled kernels.

The table shows that the dairy cow leads all other classes of live stock in the economy with which she produces human food from a given area of land. When milk is used as human food, 711.8 therms (711,800 Calories) of energy are secured from 1 acre, and 72.3 lbs. digestible protein. This fact, together with the high nutritive value of milk as a food because of its many superlative qualities (**104, 115**), explains the

[34] U. S. D. A. Farmers' Bul. 877.

steady increase in the number of dairy cattle in this country. Where only the cheese or butter produced from milk is used for human food, the acreage yield is correspondingly reduced.

Human food from an acre of staple farm products

	Yield per acre	Human food per acre	
		Digestible protein	Energy
	Lbs.	Lbs.	Therms
Dairy products			
Milk	2,190	72.3	711.8
Cheese	219	56.7	427.0
Butter	99	1.0	355.3
Meat			
Pork, 350 lbs. live wt	273	22.7	672.9
Poultry, 267 lbs. live wt	171	33.0	178.7
Mutton, 205 lbs. live wt	113	14.7	137.3
Beef, 216 lbs. live wt	125	18.5	130.0
Eggs, 122.4 dozen	184	24.6	132.2
Food crops			
Corn, 35 bu.	1,960	147.0	3,124.2
Sweet potatoes, 110 bu.	5,940	53.5	2,851.2
Irish potatoes, 100 bu.	6,000	66.0	1,908.0
Wheat, 20 bu.	1,200	110.4	1,788.0
Rice, polished (40 bu. rough rice)	1,086	50.0	1,581.2
Soybeans, 16 bu.	960	294.7	1,534.0
Peanuts, 34 bu.	524	126.2	1,265.0
Oats, 35 bu.	784	89.4	1,254.4

Next to the dairy cow in acre returns comes the hog, which yields 672.9 therms of energy in the pork produced on an acre. Far below the hog in economy of production come poultry, beef cattle, and sheep.

Among the food crops, corn excels in yield of energy, producing 3,124.2 therms per acre. Wheat, rice, and oats fall far below corn in the economy with which they furnish both protein and energy. Tho ranking relatively low as a producer of energy, soybeans lead all the crops in yield of protein per acre.

In comparing the yields of the various classes of live stock and in studying the relative returns from the food crops consumed directly as human food and from the farm animals, it should be borne in mind that beef cattle and sheep can be maintained largely, except for the fattening period, on cheap roughages, such as corn stover, straw, stubble-field pasturage, etc., much of which would otherwise be wasted. (2) Tho dairy cows require considerable concentrates, they can dispose of much roughage, even some of relatively low value, such as stover and straw. The farm flock of poultry can secure much of its feed from kitchen scraps, insects, and farm waste in general. Furthermore, in studying data of this character one must bear in mind the relative expense for labor and other items with the various classes of stock. For instance, more labor is required for each dollar's worth of product in the case of dairy cattle than with beef cattle, sheep, or swine. These estimates

present but one side of a most complicated economic question, as they show merely the relative efficiency with which the various animals and the various food crops utilize land in the production of human food.

In this connection the fact that the colored laborers in the cotton fields of the south live largely on corn meal and pork products is of interest. By the force of circumstances they have been driven in their struggle for existence to exist mainly on the crop producing the largest amount of human food per acre—Indian corn, the king of the cereals—and for the sake of variety in their food and an additional supply of protein, the most efficient meat-producing animal of the farm. Undoubtedly, better nutrition and an even more economical diet would result if they made much more use of milk.

132. Returns from feed.—According to Jordan[35] the different farm animals produce from 100 lbs. of digestible matter in feed approximately the amounts of marketable product and of edible dry matter shown in the table.

Human food produced by farm animals from 100 lbs. of digestible matter consumed

Animal	Marketable product	Edible solids	Animal	Marketable product	Edible solids
	Lbs.	Lbs.		Lbs.	Lbs.
Cow (milk)	139.0	18.0	Poultry (eggs)	19.6	5.1
Pig (dressed)	25.0	15.6	Poultry (dressed)	15.6	4.2
Cow (cheese)	14.8	9.4	Lamb (dressed)	9.6	3.2
Calf (dressed)	36.5	8.1	Steer (dressed)	8.3	2.8
Cow (butter)	6.4	5.4	Sheep (dressed)	7.0	2.6

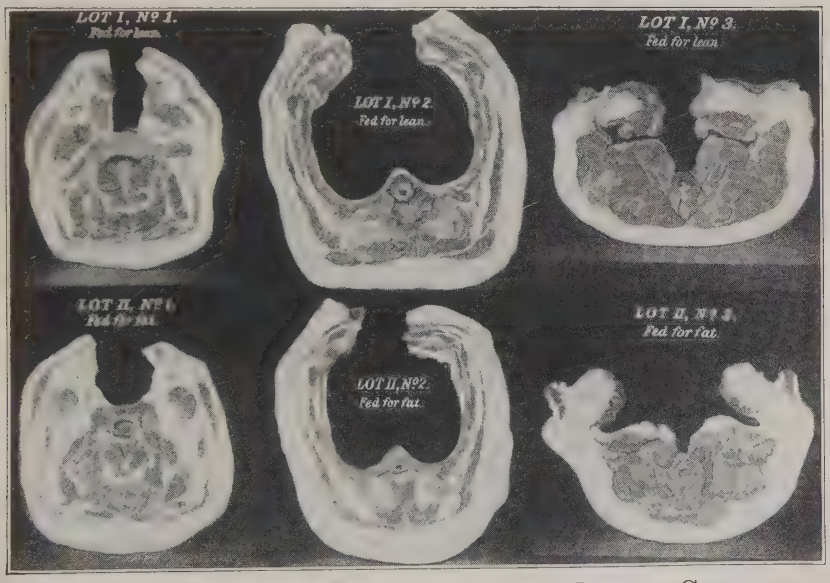
The table shows that the cow leads all classes of stock in the economy with which she converts feed into human food, producing 139 lbs. of milk, containing 18 lbs. of dry matter, from 100 lbs. of digestible matter in her feed. The pig closely rivals the cow, for it returns from 100 lbs. of digestible matter in its feed, 25 lbs. dressed carcass, containing 15.6 lbs. edible dry matter. The steer and sheep yield less than 10 lbs. of dressed carcass, nearly half of which is water. Deducting this and also the bone and gristle, there remain only 2.6 to 3.2 lbs. of water-free edible meat produced per 100 lbs. of digestible matter in the feed. Data presented in a later chapter (710) show that where steers are raised on an economical ration and marketed before being fattened to an excessive degree, a considerably larger return than this is secured. In these recent trials steers thus fed have produced 6.0 lbs. edible solids in their carcass from 100 lbs. total digestible nutrients in their feed.

133. Feeding pigs corn only.—At several experiment stations trials have been carried on to determine the effect on the growth of animals and upon the composition of their bodies of feeding unbalanced rations, which did not furnish an ample supply of protein or mineral matter. These investigations are of much practical importance as they demon-

[35]The Feeding of Animals, 1917, p. 423.

THE DAIRY COW EXCELS IN ECONOMY OF FOOD PRODUCTION

The dairy cow produces milk, an unrivaled human food, with much greater economy than beef cattle, sheep, swine, or poultry produce human food in the form of meat. For this reason, the number of dairy cows steadily grows as our population increases.

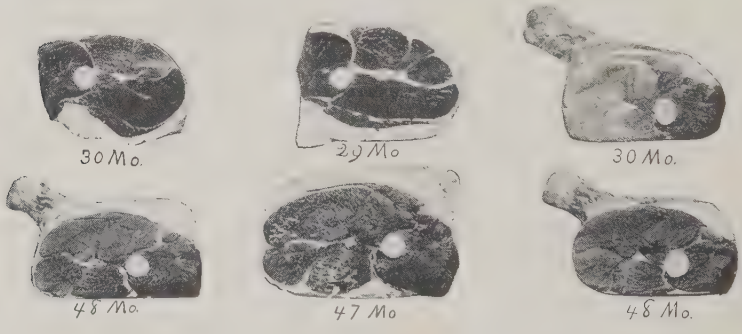


PIGS FED CORN ALONE DO NOT DEVELOP NORMAL CARCASSES

Upper row, cross sections of carcasses of pigs fed for lean; i. e., on well-balanced ration, by Henry at the Wisconsin Station. Left, section at shoulder; middle, section between fifth and sixth ribs; right, section at loins. Lower row, carcasses of pigs fed corn alone. Note larger size of muscles of pigs fed well-balanced ration.

SCANTY FEEDING STUNTS GROWING ANIMALS

The steer in the middle row of pictures, fed a full ration, weighed 1,965 lbs. when 4 years old. The steer at the left, fed a medium ration, weighed only 1,224 lbs. and the one at the right, fed a scant ration, but 1,042 lbs. Note the stunted appearance of the latter steers at the end of the trial. (From Missouri Station.)



ROUND STEAKS FROM STEERS VARIOUSLY FED

Left, from steers fed medium ration; middle, from steers fed full ration; right, from steers fed scant ration. Note large size and well-marbled appearance of muscles from the full-fed steers and the scarcity of fat in the meat from the steers fed the scant ration. (From Missouri Station.)

strate clearly the folly of failing to provide properly balanced rations for young, growing animals.

In 1884 Sanborn of the Missouri Agricultural College[36] conducted studies in which growing pigs fed exclusively on corn meal were compared with others fed on corn meal and either wheat middlings or dried blood. The corn-meal ration furnished an abundance of easily digested carbohydrates and fat, but was deficient in crude protein and mineral matter. The addition of dried blood or wheat middlings to corn meal formed a ration rich in crude protein and mineral matter as well as carbohydrates and fat. Sanborn showed that, compared with the corn-fed pigs, those getting rations rich in crude protein had a larger muscular development and more blood, and that some of their internal organs were larger.

Realizing the fundamental importance of Sanborn's studies, the senior author conducted numerous trials at the Wisconsin Station[37] in which dried blood, wheat middlings, field peas, and skim milk, with or without corn meal, were fed in opposition to corn meal alone. Shelton of the Kansas Station[38] fed pigs a mixture of wheat shorts and wheat bran in opposition to corn meal, potatoes, and tallow. At the Alabama Station[39] Duggar fed cowpeas, which are rich in crude protein, against corn meal. In France Fortier[40] duplicated a trial by the senior author, feeding skim milk, dried blood, and wheat middlings in opposition to corn meal. Thus at five widely separated points pigs were fed rations rich in protein and mineral matter, usually containing some corn meal, in opposition to corn meal alone, which is rich in carbohydrates and fat but low in crude protein and mineral matter. The following table summarizes the findings of two trials at the Wisconsin and one at the Kansas Station, these being typical of all:

Effect on pigs of rations rich in protein and ash, compared with corn alone

Station and feed	Av. daily gain	Blood	Liver	Kidneys	Tender-loin	Leaf lard	Strength of thigh bone per 100 lbs. live wt.
	Lbs.	Oz.	Oz.	Oz.	Oz.	Oz.	Lbs.
Wisconsin							
Milk, middlings, blood	1.0	54.4	26.9	5.0	17.1	79.9	503
Corn meal	0.7	41.3	24.3	4.2	13.8	89.3	380
Wisconsin							
Blood, corn meal	1.4	47.1	22.2	3.9	....	....	385
Peas, corn meal	1.2	44.7	21.3	3.4	....	....	471
Corn meal	1.1	43.8	17.7	2.8	....	....	354
Kansas							
Shorts, bran	1.4	50.4	44.7	7.4	13.0	65.1	357
Potatoes, tallow, corn meal	1.1	36.8	33.8	5.8	10.0	75.3	332

[36] Mo. Buls. 10, 14, 19.
[37] Wis. Rpts., 1886, '87, '88, '89.
[38] Kan. Bul. 9.
[39] Ala. Bul. 82.
[40] Ext. Trav. Soc. Cent. d'Agr., Dept. Seine-Inf., 1889, 1890.

The table shows that the pigs fed rations rich in crude protein and ash made greater gains than those fed rations poor in these constituents. As a rule the pigs getting the rations rich in crude protein had a larger amount of blood and heavier livers and other organs per 100 lbs. of carcass.

The strength of the thigh bones was determined in the following manner: The two rounded, iron supporting edges of a machine used for testing the breaking strength of materials were set four inches apart. On these a thigh bone was placed, the rounded edge of the breaking-bar pressing down on the bone from above, midway of its length. The downward pressure was gradually increased, being measured by the tilting beam of the machine. Under the steadily increasing pressure the bone finally broke, its resistance at the time of breaking being recorded. The trials showed that the pigs fed the ration rich in crude protein had the strongest bones. In the first Wisconsin trial, as the table shows, the bones of the corn-fed pigs broke at an average pressure of 380 lbs. for each 100 lbs. of carcass, while those of the pigs fed milk, dried blood, and middlings broke at about 500 lbs.—a difference of 32 per ct. in favor of the pigs getting the ration rich in crude protein.

In the first Wisconsin trial the pigs getting milk, wheat middlings, and dried blood had over 54 oz., or nearly 3.5 lbs., of blood for each 100 lbs. of dressed carcass, while those getting only corn meal had less than 42 oz., or but little over 2.5 lbs. The livers and kidneys of the pigs fed the rations rich in crude protein were in all cases relatively heavier, as were also the tenderloin muscles, lying along the back, showing that a superior muscular development was associated with the larger internal organs, more blood, etc. On the other hand, the carcasses of the corn-fed pigs contained an unduly large proportion of fat. Analyses of the organs and parts of the pigs used in the second Wisconsin trial showed further that the corn-fed pigs had proportionately less dry matter in their blood and kidneys and a smaller amount of dry lean-meat tissue than those on the narrow ration.

134. Cause of poor growth on corn.—It has been pointed out previously that corn is low both in protein and in mineral matter, especially lime, considerable of which is required to develop the skeletons of young animals. The protein of the corn grain is also unbalanced in composition, containing large amounts of some of the amino acids, or protein building stones, and only small amounts of some of the others which are necessary for growth. (118) The question therefore arises as to what is the chief deficiency of corn: (1) too small an amount of protein, (2) unbalanced protein, or (3) a deficiency in lime?

To study the effect of adding a supply of lime to a ration of corn alone, the senior author[41] carried on 3 experiments in each of which one lot of pigs was fed corn alone; a second lot, corn and hard-wood ashes, which are rich in lime; and a third lot, corn and bone meal. The pigs were

[41]Wis. Rpt. 1890, Bul. 25.

confined in pens, with exercise yards floored with boards, so the pigs could eat no dirt. The pigs fed corn alone soon failed to grow and became unduly fat and dwarfed. Those receiving wood ashes or bone meal in addition grew quite well for a time, but later their gains were poor. On corn alone 629 lbs. of corn was required for 100 lbs. gain in weight, while only about 490 lbs. of corn was required when wood ashes or bone meal was added. Also the bones of the pigs fed corn alone were only half as strong as those of the others. These trials clearly showed that adding a liberal supply of lime to the ration was of some benefit but did not entirely remedy the deficiencies of corn for growing animals.

In later years numerous trials have been carried on by scientists to study this matter further. These investigations have clearly shown that to make a complete and satisfactory ration for growing animals, there must be added to corn not only a supply of lime, but also an additional supply of protein, and furthermore protein which is better balanced in composition than that which the corn grain furnishes. (118) Recent studies have also shown plainly that for pigs not on pasture, the amount of fat-soluble vitamine in white corn is too low for normal growth. (202, 939)

The earlier trials with corn alone were carried on chiefly with pigs which were fairly well grown when the experiments began. Extensive experiments carried on at the Kansas Station by Waters, Cochel, Hogan, and Vestal have shown in a striking manner that young pigs can not be raised on corn alone. In a trial reported by Hogan[42] pigs weighing about 25 lbs. were fed corn with various supplements. On corn plus a mixture of mineral matter containing an ample supply of lime, pigs made practically no growth, gaining only 12 lbs. each in 180 days! However, when not only mineral matter but also milk casein, a well-balanced protein, was added to corn, the pigs gained 179 lbs. each in the same time.

The effect of feeding varying amounts of protein when an abundance of mineral matter was supplied was studied by Grindley and colleagues at the Illinois Station.[43] Pigs fed rations very high in protein had larger livers and kidneys, and heavier and stronger bones than when a smaller amount of protein-rich feed (blood meal) was supplied. No difference was found in the forms of nitrogenous compounds in the protein tissues or in the distribution of the mineral matter among the various organs of the body.

135. Discussion of the pig-feeding experiments.—These experiments are of profound importance in pointing out the requirements of growing animals and in showing the effects of feeding them rations which are not properly balanced. Only by paying heed to these basic facts can live stock be raised on the farm at the minimum of expense and, especially, only thus can the breeder of pure-bred stock make the desired improvement in his herds or flocks.

[42] Jour. Biol. Chem., 29, 1917, pp. 485-493.
[43] Ill. Buls. 168, 169, 171, 173.

These experiments should impress upon the stockman the plastic nature of the bodies of young, growing animals. They show it possible for immature animals living on unsuitable food to survive a long time and develop bodies that are dwarfed in size and made unnaturally fat. They help to show that Nature's plan is first to grow the body framework and afterwards to lay on the fat. They point to the reasonable, important, and far-reaching conclusion that if a pig or other young animal is improperly fed so as to modify its bones, muscles, and vital organs even a very little, and the process is repeated during several generations, the cumulative effects of this on the offspring will be marked. The practical lesson is taught that young animals should be nurtured on a combination of feeding stuffs that will develop the normal framework of bone, muscle, and all body organs. This calls for a ration containing crude protein and mineral matter not only in ample amount, but also of suitable composition for rapid formation of body tissues. Having developed the proper framework of bone, together with the enveloping muscular system and all the organs of the body, the food supply may then consist largely of carbohydrates and fat, which are the cheap and abundant sources of animal fat.

In America corn is the common feeding stuff for swine, and pigs show such fondness for it that harm often results, because the practice of the feeder and breeder is guided by the appetite of the animal rather than by a knowledge of the composition and limitations of feeds. Let us not find fault with corn because when wrongly and excessively used, as it purposely was in these experiments with young, growing pigs, it fails to develop the normal framework of bone and muscle. Each feed has its function in the nutrition of animals, and only by its abuse can unfavorable results follow.

136. Wide and narrow rations for growing steers.—The effect of a ration rich in crude protein and of one quite low in protein on the rate of growth and the character of flesh formed by growing steers was studied in an experiment by Jordan at the Maine Station.[44] Two high-grade Shorthorn steer calves, 5 to 7 months old when the trial began, were fed a ration rich in protein, made up of a concentrate mixture of 2 parts of linseed meal, 1 part of wheat bran, and 1 part of corn, with timothy hay, corn fodder, and corn silage for roughage. A second lot of 2 calves was fed a ration low in protein, consisting of the same roughages as the first pair and a concentrate mixture composed of 2 parts corn and 1 part of wheat bran. The ration fed Lot I had the narrow nutritive ratio of 1:5.2, while that fed Lot II had the wide nutritive ratio of 1:9.7. The ration fed Lot I in this trial was not nearly so deficient for promoting growth as a ration of corn alone for young pigs, for it was fairly high in mineral matter and furthermore the protein, tho low in amount, was better balanced in composition than that furnished by corn grain alone.

[44] Maine Rpt. 1895.

At the end of 17 months the steers fed the protein-rich ration had each gained 105 lbs. more on the average than those fed the protein-poor ration, and they also appeared much more thrifty. One steer from each pair was then slaughtered and the carcasses were analyzed. The other steers were continued on the same rations for 10 months longer. They were then likewise slaughtered and their carcasses analyzed. During this latter period the steer fed the ration fairly low in protein gained even faster than the one fed the ration high in protein. This was due to the fact that the protein tissues of the body had already been largely grown, and the gain consisted chiefly of fat. There was no marked difference in the composition of the carcasses of the steers fed these rations, owing undoubtedly to the fact previously mentioned; i. e., that the protein-low ration was not so poor a ration as corn alone for pigs.

These data demonstrate the truth of the statement previously made (**115**), that a ration rich in protein favors rapid growth of young animals. On the other hand, when the body is partly or largely grown, the largest gains, which are then mostly fat, come from liberal feeding with rations which are rich in digestible carbohydrates and rather limited in crude protein; i. e., having a comparatively wide nutritive ratio. Doubtless more economical results than were secured with either lot would have been obtained had these steers been fed a fairly narrow ration the first year, and then fattened on a wider ration. Trials with larger numbers of animals, already mentioned (**129**), show that the largest gains are made by 2-year-old steers when fed a somewhat narrower ration than the wide one fed by Jordan.

137. Growth under adverse conditions.—Extensive experiments carried on at the Missouri[45] and Kansas[46] Stations are of much interest in showing what happens when young animals are fed only enough feed to maintain their weights. In these trials some steers have been grown to maturity on liberal rations, while others for periods of several months have been fed rations so scant that they could make no gain in live weight. Still others were fed sub-maintenance rations, supplying so little feed that the steers steadily lost weight. One of the primary objects of these experiments was to find whether such scant feeding permanently stunts the animal. This matter is of great practical importance, because under range conditions the feed during the winter is often so sparse that the young cattle weigh considerably less in the spring than they did in the fall. Also under farm conditions it is quite a common practice to feed young stocker steers which are not to be fattened for market immediately, a ration consisting chiefly of cheap roughage, on which they will make but little gain in weight.

In some of the trials at the Missouri Station by Waters and P. F.

[45]Waters and Trowbridge, Proc. Soc. Prom. Agr. Sci. 1908; information to the authors; Trowbridge, Moulton, and Haigh, Mo. Res. Buls. 28 and 43.

[46]Waters, Cochel, and Vestal, Kansas Industrialist, May 10, 1913; Apr. 18, 1914; and information to the authors.

Trowbridge young steers weighing 573 to 740 lbs. at the start were fed rations only sufficient to maintain their weight. Due to their pronounced impulse toward growth, they continued to grow in height even tho they did not increase in weight. In this effort the fat stored in the body was withdrawn and used up as body fuel, the animals becoming thin in flesh as the scanty feeding progressed. For 70 to 120 days, depending on how vigorous they were and how much fat they carried, these steers gained as rapidly in height as others on full feed. After this period the increase in height became less rapid, ceasing altogether in from 6 months to a year and a half, by which time the animals had become quite thin and had burned up all the fat in their bodies which was not absolutely necessary to life.

The striking changes which are produced in the composition of the fatty tissues, lean flesh, and skeletons of animals fed scanty rations are shown in the following table. This gives the composition of the body tissues of a steer slaughtered at the beginning of the trial as a check animal, of a steer fed for 12 months a ration sufficient only to maintain its weight, of one fed so little feed for 12 months that it lost 0.5 lb. a day, and of one fed a fairly liberal ration for 5 months:

Changes in body tissues of steers on scanty and liberal rations

	Steer I, check animal	Steer II, on maintenance 12 months	Steer III, losing 0.5 lb. per day for 12 mo.	Steer IV, gaining 0.5 lb. daily for 5 mo.
	Per ct.	Per ct.	Per ct.	Per ct.
Fatty tissue				
Water	19.0	36.2	81.2	18.5
Fat	74.8	50.8	4.6	73.4
Protein	6.0	13.6	9.7	6.5
Ash	0.2	0.5	1.1	0.2
Lean flesh				
Water	71.0	74.0	76.9	71.1
Fat	8.0	4.6	2.1	7.8
Protein	20.1	19.7	19.8	19.2
Ash	0.9	1.0	1.0	0.9
Skeleton				
Water	37.1	36.2	52.6	35.4
Fat	14.7	16.4	2.9	17.3
Protein	20.4	20.0	19.1	19.8
Ash	25.3	26.6	22.8	25.3

The table shows that in the case of Steer II, held at constant weight for 12 months, much fat had been withdrawn from the fatty tissue, being largely replaced by water. So far had the withdrawal of fat progressed in the case of Steer III, that the small amount of "fatty tissue" which was secured from the carcass contained 81.2 per ct. water and only 4.6 per ct. fat! With the withdrawal of fat the percentage of protein and ash had increased. The lean flesh suffered much less change than the fatty tissues, even in the case of Steer III, which lost nearly 40 per ct. of the lean meat in his body during the trial. The data show that on

insufficient food the fat was withdrawn to a marked degree from the lean flesh of the body.

The skeleton is not affected by poor nutrition until practically all the fat has been removed from the fatty tissues and the muscles. In the case of Steer III the withdrawal of fat had gone so far that nearly all the fat had been removed from the marrow of the skeleton and replaced with water. Indeed, the marrow had practically disappeared and in its place was a watery, ill-smelling liquid. This re-absorption of fat takes place from all parts of the skeleton. In contrast with these changes, the percentages of protein and ash were but slightly reduced, even in the case of Steer III.

In the process of fattening, the fat is laid on the body in a certain order, being deposited first and most rapidly in certain regions, while in others little is stored until fattening is well advanced. Waters states that the withdrawal of fat from the tissues occurs in the reverse order from which it was laid on—that first deposited being the last to be absorbed.

As a result of these studies Waters points out that a young animal may reach normal size by any or all of the following ways:

1. By growing steadily from birth to maturity.
2. By storing fat during a period of abundant food supply, which will help to tide over a limited period of sparse food supply without serious checking of growth.
3. By prolonging the growth period.
4. By an increase in the rate of growth during a period of liberal feeding following a period of scanty feeding and low gain.
5. By using its food more efficiently. Apparently when an animal is kept for a limited period on scanty food, it gets on a more economical basis than when liberally fed. A ration which is at first insufficient to maintain an animal may be capable later of keeping the same animal at a constant body weight, and still later of causing a small gain. If it becomes unthrifty due to partial starvation, it will then digest its food less completely.

138. Effects of checking growth.—In the experiments at the Kansas Station, Waters, Cochel, and Vestal studied the effect on pure-bred beef steers of checking their growth for various periods by under-feeding. They report that supplying a young, growing animal with a scant ration for a short period only will have no permanent effect on its development. Even when insufficient feeding is continued for a year or longer, the animal will recover to a surprising extent when placed on liberal feed, making unusually rapid and economical gains. Osborne and Mendel[47] have shown that while the normal growth period of rats rarely exceeds 335 days, those whose growth has been checked by insufficient food will resume growth even at the age of 480 to 532 days.

[47]Jour. Biol. Chem., 18, 1914, pp. 95–106.

The Kansas experiments show, however, that while a steer whose growth has been checked for a year or more may grow nearly as tall as one fed well all along, it is almost certain to have a smaller digestive capacity, narrower hips, flatter ribs, heavier shoulders, and lighter hind quarters, even when finished for market.

In experiments at the Missouri Station[48] conducted by Moulton, Trowbridge, and Haigh to study the effect of scanty feeding on growth, three groups of steers were fed different amounts of the same feeds from a few weeks of age for four years. One lot was full fed from birth. A second lot was given a medium ration, being supplied sufficient feed for maximum growth without appreciable fattening. A third lot was fed a scant ration, being given only enough feed to enable them to gain about 0.5 lb. a head daily. The steers which were scantily fed grew less rapidly in all respects than those given a liberal ration. They were in the poor condition one would expect in animals not being properly cared for. These steers always suffered more severely from indigestion, pink eye, and other ailments, and there was considerable mortality among them. At 4 years of age they had reached the same height attained by the full-fed group, but they were decidedly stunted in length, width, and circumference of the body. The scant ration had no apparent effect on the breaking strength of the bones, due undoubtedly to the fact that alfalfa hay, rich in calcium and phosphorus, was the roughage fed.

These studies on growth are highly significant to the stockman. They show that under certain conditions it may be profitable to carry growing animals thru the winter on roughages alone, even tho they lose slightly in weight, for on a return to good pasture, animals in spare but thrifty condition make exceedingly economical gains. However, the breeder who seeks to develop his animals toward an ideal must supply ample feed during the whole growth period.

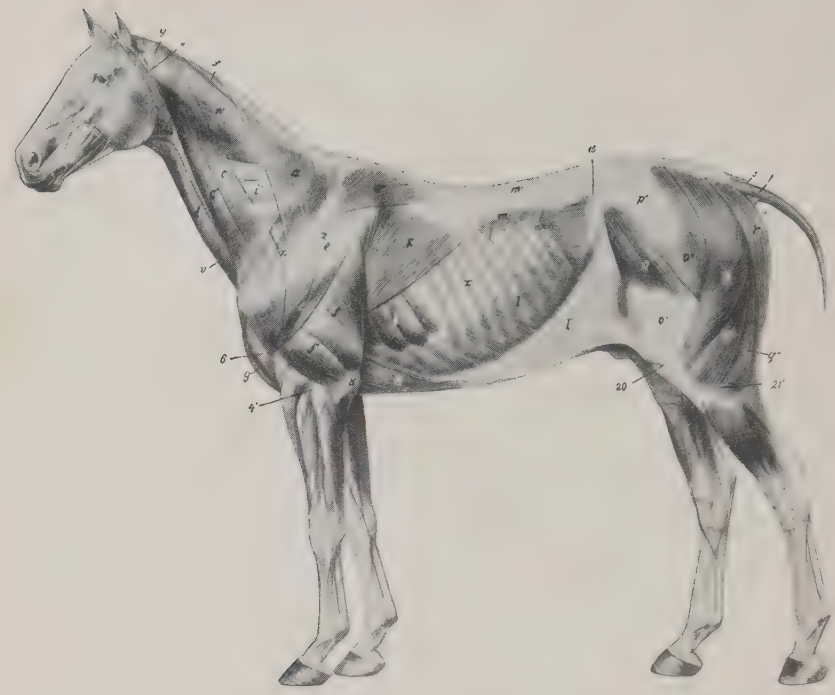
[48]Mo. Res. Bul. 43.

HORSES AT HARD WORK REQUIRE MUCH NET ENERGY IN FEED

On account of the large amount of energy they expend in the work they perform, horses at hard work must receive a liberal amount of concentrates high in net energy.

HIGH-PRODUCING DAIRY COWS ALSO REQUIRE MUCH NET ENERGY

Many people fail to realize that high-producing cows are expending as much energy in producing milk as horses at hard work expend in their labor.



THE MUSCULAR SYSTEM OF THE HORSE

The work done yearly in this country by horses and mules is worth over $2,000,000,000. (From Ellenberger.)

LEFT—SMALL PORTION OF MAMMARY GLAND OF COW

Small portion of gland, greatly magnified. A, alveoli, in which milk is secreted, b, small milk duct; c, larger milk duct. See Page 107. (After Klein.)

RIGHT—WOOL FIBERS

Appearance of fibers, greatly magnified, after dirt and yolk have been removed. Left, fiber of Merino wool; right, fiber of Down wool. Note the overlapping scales covering the fibers. See Page 110.

CHAPTER VI

PRODUCTION OF WORK, MILK, AND WOOL

I. Production of Work

It has long been known that muscular exertion or external body work greatly increases the amount of food material burned or broken down in the body, but scientists have disagreed as to whether one or all of the nutrients—protein, carbohydrates, or fat—furnishes the energy.

139. The source of muscular energy.—Because external work is brought about by contractions of the muscles, it was perhaps natural that early scientists believed the muscles, which are composed of protein tissues, were themselves broken down to furnish the energy used in the work. For instance, Liebig, the "father of agricultural chemistry," maintained that the protein of the muscle tissues was the only material used up in producing voluntary or involuntary motions, whether of the limbs, heart, or other parts of the body. When metabolism trials were carried on by various scientists to study the production of work by animals, the results disagreed. In some cases, the amount of nitrogen excreted in the urine was much greater when work was performed, indicating that protein had been broken down in the body in the production of the muscular energy. However, in other trials no more nitrogen was excreted during work than during rest.

The first clear light was thrown on this matter by Fick and Wislicenus,[1] who in 1865 ascended the Faulhorn, an Alpine mountain 6,418 feet high, to study the effect of the work of climbing upon their own bodies. While ascending the mountain they consumed only non-protein food; i. e., starch, sugar, and fat, and during this time they collected all the urine passed. Had the muscles or other protein tissues of the body been broken down in producing the muscular labor involved in climbing the mountain, there would have been a large increase in the amount of nitrogenous waste material excreted in the urine during and immediately after the climb. But this was not the case. On analysis, it was found that no more nitrogen was excreted than before the climb when no work was being done. Measured by the nitrogen in the urine, the protein broken down during the trial could not possibly have furnished energy for more than one-third of the work done by these men in lifting their bodies to the top of the mountain, making no allowance whatsoever for the work of the internal organs of the body, nor for the muscular exertions which did not contribute directly to the work of climbing.

[1] U. S. Dept. Agr., Office of Expt. Sta., Bul. 22, p. 307.

From this trial and experiments by Voit, Pettenkoffer, and Parks, it was believed for a time that the carbohydrates and fats served as the only source of muscular energy. The whole matter was cleared up only after still later investigations by Kellner, Argutinsky, and Zuntz. These trials showed that when the food contains sufficient carbohydrates and fat, these nutrients furnish all the energy used up in work, and in such cases the breaking down of protein in the body is not increased. On the other hand, if the supply of carbohydrates and fat in the food is insufficient, some of the energy for the production of the work will be furnished thru the breaking down of protein, with a resultant increase in the nitrogen excreted in the urine. Because the feed supplied work animals is usually composed chiefly of carbohydrates, this class of nutrients ordinarily furnishes practically all the energy animals use in their labor.

Investigations by Zuntz and his associates[2] show that the value of each of the different classes of food nutrients for the production of work depends on the amount of net energy which each class furnishes the animal. This is because the net energy, or the amount remaining after deducting all the losses which occur in the feces, urine, and combustible gases, and in the "work of digestion," is the only part of the total energy of the feed which can be turned into muscular work.

140. Production of muscular energy.—We know that in doing work the muscles of the body contract; that is, become shorter and thicker. Yet, in spite of all the study of scientists, we do not know definitely the direct cause of muscular contraction. How the nutrients stored in the muscular tissues are converted into the energy of muscular action is still an unsolved question. We do know, however, some of the processes which take place in the working muscles.

The most significant change which takes place during muscular contraction is an immediate and marked increase in the production of carbon dioxid in the body. By determining the amount of this gas exhaled from the lungs, it has been found repeatedly that, unlike the amount of nitrogen voided, the amount of carbon dioxid which is excreted depends directly on the amount of work performed. For example, Smith[3] found that when at rest a horse exhaled 1.03 cubic ft. of carbon dioxid per hour. When the horse was walking slowly the excretion rose to 1.10 cubic ft., and as the gait became faster and consequently the rate of work increased, the amount became much larger, as follows: When trotting, 2.95 cubic ft. per hour; when cantering, 4.92 cubic ft.; and when galloping 14.97 cubic ft.

During work there is also a large increase in the amount of oxygen taken up by the muscles from the blood and an increased production of water in the muscular tissues. The increase in oxygen consumed and carbon dioxid given off might lead to the conclusion that the activity of the muscle during contraction is due to simple oxidation, such as occurs when fuel is burned. However, certain facts which cannot be dwelt

[2] Arch. Physiol. (Pflüger), 83, 1901, p. 564. [3] Jour. Physiol., 1890, No. 1.

upon here lead scientists to believe that the chemical changes by which energy is liberated are not simple oxidations, but are more in the nature of sudden decompositions or cleavages of some complex substance or substances built up in the muscle during rest, carbon dioxid being evolved in such cleavage. Part of the energy liberated in this decomposition appears as heat, and another part as mechanical work.[4]

Glycogen, or animal starch, is stored in the muscle during rest, forming between 0.5 and 0.9 per ct. of the weight of well-nourished muscle in the resting condition. (**60**) A smaller quantity of glucose is also found in the muscular tissues. During muscular activity this stored glycogen and glucose disappear, in proportion to the extent and duration of the contractions, so that after prolonged muscular activity or hard work the supply may be entirely exhausted. Tho the amount of these carbohydrates in the body tissues at any one time is small, a supply, especially of glucose, is being continuously produced from the food nutrients or body tissues to replace that oxidized in the production of work. As the larger part of the food of farm animals consists of carbohydrates, the oxidation of the glucose formed from them probably furnishes most of the energy for the production of heat and work by these animals. To supply the muscles with the necessary oxygen and also carry away the waste products formed during muscular exertion, the circulation of the blood must be hastened and larger quantities of air be taken in by the lungs.

141. Food requirements for work animals.—We have seen in the preceding paragraphs that theoretically an animal needs no more protein in its feed when at work than when idle, since the energy used in the production of work is normally furnished by the carbohydrates of the ration or by the fat in some instances. Protein is used up in work only when the ration contains insufficient of these other nutrients. In trials mentioned later (**454**), work horses have been successfully fed rations in which the nutritive ratio was as wide as 1:21 to 1:28. However, as has been pointed out previously (**84**), when the nutritive ratio is wider than 1:8 or 1:10, the digestibility of a ration is usually decreased, causing a waste of feed. Also, it is believed that a supply of protein somewhat above the minimum requirements tends to give work animals better life and spirit. Accordingly, in the Morrison feeding standards, nutritive ratios not wider than 1:7.0 to 1:8.5 are recommended, a somewhat narrower nutritive ratio being advised for hard work than for light work. (Appendix Table V.) The mature animal when at work has need for but little more mineral matter than an idle one which is merely being maintained. Therefore, all ordinary rations will furnish an ample supply of the various mineral nutrients, except common salt. Immature work animals, which have not yet reached full size, will need a somewhat more liberal supply of protein and mineral matter than mature ones.

From the foregoing, it is evident that the primary need in rations

[4] Armsby, Nutrition of Farm Animals, pp. 533-4.

for work animals is for a sufficient supply of feeds rich in easily digested carbohydrates, and which consequently yield a large amount of net energy. Hence the most common rations for horses at hard work are made up of only a moderate amount of hay or other roughage, with a liberal supply of farm grains, such as oats, corn, or barley, which are rich in net energy. If the rest of the ration is very low in protein, a small amount of protein-rich feeds should be added to balance the ration according to the recommendations of the feeding standards. The harder the labor performed, the larger should be the proportion of grain to roughage in the ration. Detailed discussions of the feed requirements of horses for various classes of work are given in Chapters XVIII and XX. (454-6, 530, 536-8)

142. Factors influencing energy required for work.—The amount of energy required to produce a given amount of useful work depends upon many factors. Practice in doing a certain kind of work lessens the amount of energy expended. For instance, in experiments upon himself Gruber[5] found that after training for 2 weeks the energy he used in climbing a certain tower was decreased by over 20 per ct. On the other hand, experiments by Löwy[6] and by Zuntz[7] show that fatigue causes a considerable increase, ranging from 14 to 41 per ct., in the amount of energy expended in performing a given amount of work. This is largely due to the fact that with increasing fatigue the muscles normally used, and which are thus most efficient in performing the given work, are put out of use. Then other less used muscles are called upon to a constantly increasing degree, and these cannot perform the work so economically.

The part of the expended energy appearing in useful work also varies with the build of the animal, the development of its muscles, and the structure of its limbs. For example, Zuntz found that a lame horse expended 99 per ct. more energy in traveling a given distance than a sound one. In the work of climbing a grade he found a variation with different horses of as much as 52 per ct. in the proportion of the total energy expended which appeared as useful work. An animal which is able to accomplish one form of work most economically may have to expend an unusual amount of energy on other kinds of work. For example, horses bred for generations to the saddle can carry the rider with a smaller expenditure of energy than those whose breeding, form, and qualities specially fit them for draft purposes.

Certain forms of labor are performed with greater economy of energy than others. Katzenstein[8] found in experiments with men that about 65 per ct. more energy was used in turning a wheel with the arm than was required when the same work was done with the leg.

The experiments by Zuntz show that increasing the speed at which work is done also lessens the efficiency with which it is performed. This

[5]Ztschr. Biol., 38, 1891, p. 466.
[6]Arch. Physiol., 49, 1891, p. 413.
[7]Landw. Jahrb., 27, 1898, Sup. III.
[8]Wolff, Farm Foods, p. 84.

is because the work of the heart is increased, the body temperature rises, and much heat is lost by the evaporation of water thru the skin and lungs. This decreases the amount of work which a given quantity of food will produce. Furthermore, in trotting or galloping the rise and fall of the body is much greater than in walking, and therefore the horse has available for onward movement a smaller part of the total energy he expends.

143. The animal as a machine.—The extensive investigations by Zuntz and his associates on men, dogs, and horses show that, aside from small variations due to the nature of the work and other factors, the part of the energy expended which is actually transformed into external work is quite constant for each class. Animals working at a moderate rate of speed converted into external useful work from 28.8 to 36.6 per ct. (on the average about one-third) of the additional energy they expended during the work. The rest of the energy used up takes the form of heat within the body and is lost so far as the production of work is concerned. This does not take into consideration the energy of the feed lost in the feces and urine, nor that expended in the work of digestion and in the ordinary maintenance of the body.

It is shown in Chapter XVIII that when a horse is working at full capacity during the day, it will convert about 8 per ct. or more of the gross energy of its feed into actual useful external work, such as hauling a load, without counting the energy expended in the work of moving its own body. (458) If credit is also given for this work of locomotion of the body, the percentage efficiency is 15 per ct. or more.

Compared with these estimates of the efficiency of animals as machines, it was found in recent tests of 65 different farm tractors at the University of Nebraska[9] that on the average the tractors converted 8.0 per ct. of the gross energy of the fuel (chiefly kerosene) into work of draft, which did not include the work of locomotion of the tractor itself. In developing belt power, where there was no work of locomotion, the tractors on the average turned 13.4 per ct. of the gross energy of their fuel into the work performed. This may be compared to the efficiency of 15 per ct. or more for the horse, when credit is included for the work of moving the body. Thus, as a mere machine, the animal compares favorably with the best modern tractors.

The efficiency of the animal as a machine is especially striking when it is borne in mind that the tractor is supplied with purified fuel (kerosene or gasoline) from which impurities and waste material have been largely removed by distillation. On the other hand, the horse must secure its energy from crude materials, including hay, of which only about half is actually digestible. Furthermore, he must digest this feed and himself separate out the useful from the waste material. Also, he must transport the fuel he secures from his feed and make all body repairs. Last but not least, he must maintain his body during the part of

[9]Nebraska Tractor Tests, 1921.

the time he is not working, while when the tractor stops work, all expenditure of energy ceases.

144. The body not a heat machine.—Sometimes the erroneous idea is gained that the animal body is a heat machine; i.e., that muscular work is derived from heat produced by the oxidation of nutrients in the muscular tissues. However, the body is not like a steam power plant, in which the work is derived from the heat produced by the burning coal. In the animal body the energy of the food is transformed into work in quite another way, which is more similar to the production of power in an internal combustion engine, such as the gasoline engine. In this the part of the energy liberated by the explosion of the gas is converted directly into the energy of motion and produces the work accomplished. Another part is changed into heat and is wasted, so far as any useful purpose is concerned, and must be gotten rid of by the cooling system of the engine. Similarly, by some mysterious means a sudden decomposition of the food nutrients occurs in the muscles of the animal with the direct production of muscular work and also the formation of heat as a waste product.

A knowledge of the complicated processes going on in the animal body in the regulation of its manifold activities causes us to marvel at its economy and perfection. By processes still unknown the animal machine produces muscular energy, heat, light, and electricity with surprising efficiency. Moreover, with animals the fuel is burned at a low temperature. The glow worm and firefly produce light without sensible loss of heat or other energy and the torpedo fish and electric eel generate electricity by means unknown. Scientists and inventors alike are baffled by the mysterious and wonderful processes continuously occurring in the animal body.

As the horse is the principal animal machine for performing work, this subject is appropriately continued in Chapter XVIII.

II. Production of Milk

145. Secretion of milk.—Milk, the marvelous fluid designed by Nature for the nourishment of the young of all mammals, is secreted by special organs, called the mammary glands. Scientists disagree as to the exact process by which the milk is formed in the small sac-like bodies, known as *alveoli*, in the udder. However, we do know that the blood, laden with nutrients, is brought by the capillaries of the udder to the alveoli. The nutrients then pass thru the walls of the capillaries into the alveoli, where by one of Nature's wonderful processes they are converted into milk, which differs entirely in composition from the blood, whence it originates. The chief proteins of milk—casein and milk albumin—differ from all other proteins of the body, and the milk fat also has entirely different properties from the body fat of the same animal. Milk sugar, the carbohydrate of milk, is found nowhere else in the body. While the

blood contains much more sodium than potassium, in milk potassium predominates.

From the alveoli the milk passes into the network of milk ducts. In some animals the large milk ducts open directly on the surface of the teat, but in others, including the cow, they open into a small cavity, called the milk cistern, which is just above the teat. Most of the milk yielded at one milking is secreted during the milking process, for in the udder there is room for the storage of but a small part of the total amount produced.

Tho the secretion of milk is involuntary and cannot be prevented by the animal any more than can breathing or the circulation of the blood, the flow may be reduced by nervousness caused by fright, an unfamiliar attendant, or other unusual excitement. The animal probably has no power to "hold up" the milk already secreted in the udder, but fright or pain may cause the glands of the udder to cease secreting milk for the time being.

Only in most exceptional cases does the true secreting tissue of the mammary gland develop before the animal becomes pregnant. However, when an extract is made from an unborn fetus and injected into the blood of a virgin animal, the mammary gland develops just as tho the animal were pregnant. This leads scientists to believe that in the developing fetus a mysterious chemical messenger, or "hormone," is formed, which is carried by the blood to the udder, and there stimulates the development of the alveoli—an example of the surprising degree to which the activities of the body are dependent on each other.

146. The source of fat in milk.—For many years it was believed that the cow could form the fat of milk only from fat in her food. This was disproved by Jordan and Jenter[10] of the New York (Geneva) Station by an ingenious experiment. A thousand pounds of hay and 1,500 lbs. each of corn meal and ground oats were sent to a new-process oil-meal factory, where nearly all the fat was extracted with gasoline in the percolators employed for extracting the oil from crushed flax seed. (253) The almost fat-free feeds were returned to the Station and afterwards fed to a cow which had freshened about 4 months before. For 95 days the cow lived on these feeds, yet during this period she produced 62.9 lbs. of fat in her milk. The food she consumed contained but 11.6 lbs. of fat, of which only 5.7 lbs. was digested. Therefore at least 57.2 lbs. of the fat found in the milk must have been derived from some other source than the fat in the food. This fat could not have come from the body of the cow, for Jordan writes: "The cow's body could have contained scarcely more than 60 lbs. of fat at the beginning of the experiment; she gained 47 lbs. in weight during this period with no increase of body nitrogen, and was judged to be a much fatter cow at the end; the formation of this quantity of milk fat from the body fat would have caused a marked condition of emaciation, which, because of an increase

[10](Geneva) Bul. 132.

in the body weight, would have required the improbable increase in the body of 104 lbs. of water and intestinal contents."

Jordan concludes that not over 17 lbs. of the fat produced during the trial could possibly have been produced from the protein supplied in the food. It is most evident that a large part of all the fat produced by this cow must have come from the carbohydrates in her feed, and so a long disputed question was at length settled.

147. Nutrients required for milk production.—To aid in showing the nutrients required for the production of milk, let us compute the amount of product yielded by a well-bred dairy cow in the course of a year. Such an animal, of no unusual ability, should yield 8,000 lbs. of milk of average quality. Taking the composition shown in a previous table (**115**), we find that she will produce annually in her milk 272 lbs. of protein, 296 lbs. of fat, 392 lbs. of milk sugar, and 56 lbs. of mineral matter. This is 56 per ct. more protein, 30 per ct. more non-nitrogenous nutrients and 19 per ct. more mineral matter than is contained in the entire body of a fat 2-year-old steer weighing 1,200 lbs. (**29**)

Thus each year the cow yields more protein and mineral matter than has been built into the body of the steer during its entire life. At the same time she is also storing considerable protein and mineral matter in the developing body of her unborn calf. It is therefore evident that, far different from the requirements of the mature horse at work or of a mature fattening animal (**141, 129**), the cow needs a liberal supply of protein and mineral matter. To yield the great amount of nutriment in the milk, a ration supplying a large amount of net nutrients is also necessary, for energy used up in the mastication, digestion, and assimilation of such feeds as straw is of no value for the formation of milk.

148. Protein requirements for milk production.—We have seen (**118**) that for growth individual proteins have widely different values. Hart and Humphrey[11] have found in recent metabolism experiments with dairy cows at the Wisconsin Station that proteins from various sources may sometimes be of different worth for milk production. When fed with corn stover as the only roughage, protein from gluten feed or from the entire corn or wheat grains (much of which is unbalanced in composition) was distinctly inferior to milk protein or to the protein of linseed meal or distillers' dried grains. However, with clover hay and corn silage as the roughages, there was little difference in the efficiency of gluten feed, linseed meal, distillers' grains, or cottonseed meal as sources of protein. With alfalfa hay and corn silage, distillers' grains were slightly superior and cottonseed meal slightly lower in efficiency than gluten feed or linseed meal. Where legume hay forms a considerable part of the roughage for dairy cows, there is probably not much difference in the feeding value of a pound of digestible crude protein in the common protein-rich concentrates. (**573**)

[11]Jour. Biol. Chem., 21, 1915, p. 239; 26, 1916, p. 457; 31, 1917, p. 445; 35, 1918, p. 367.

1. Longitudinal Section thru One Side of Udder and Teats of Cow

The narrow duct at the end of the teat, or the teat canal, may be seen, also the cavity in the teat, and the milk cistern. Altho there is no septum, or visible division, between the fore and hind quarters, no communication exists between the milk ducts in the two quarters. In this section the tissue of the fore quarter is colored slightly lighter than that of the hind quarter.

2. Horizontal Section of the Four Quarters of the Cow's Udder

The septum, or division, between the right and left halves of the udder is clearly visible. Note the size and distribution of the milk ducts.

3. Milk Cistern and Milk Ducts of a Fore Quarter of Udder

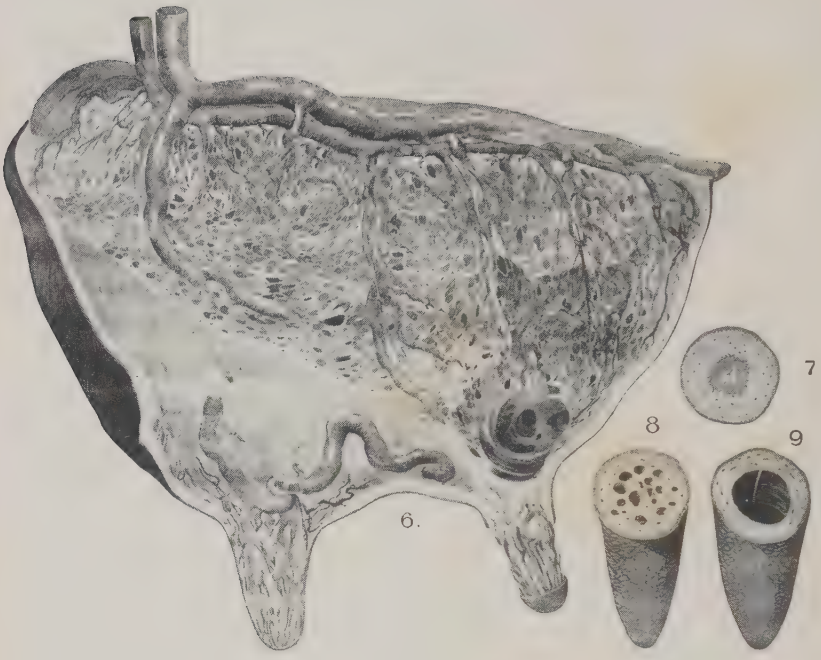
A metallic cast of the milk cistern and the larger milk ducts of one of the fore quarters.

4. Cross-section of an Alveolus Before Milking

The alveoli are small sac-like bodies, lined with secreting cells. The droplets of fat, indicated in the figure by the light-colored spots in the cells, are discharged into the cavity of the alveolus thru the cell walls when milk is secreted.

5. Cross-section of an Alveolus After Milking

This should be contrasted with Figure 4, as it shows the appearance of the cells of the alveolus following secretion. Note that the cells have lost their fat droplets and their fluid to a large degree. (Reproduced from charts by Rubeli, Berne, Switzerland.)



6. Blood Vessels of the Udder of the Cow

In this drawing both the arteries and the veins are shown. From the lower left-hand portion of the udder only the skin has been removed. In the portion above this and in all of the rear quarter the blood vessels and the secretory tissue of the udder have been exposed. Note the network of blood vessels in the teats.

7. Cross-section Near the End of a Cow's Teat

The triangular figure in the center is the narrow duct, or teat canal, at the end of the teat.

8. Cross-section of the Upper Part of a Cow's Teat Between Times of Milking

The round figures indicate the blood vessels and the irregular, slit-like figure at the center, the contracted cavity of the teat. Note the large size of the blood vessels and the small size of the teat cavity.

9. Cross-section at the Same Point During Milking

Note that the teat cavity is distended, while the blood vessels are contracted and carry relatively little blood. (From charts by Rubeli, Berne, Switzerland.)

149. Mineral matter required for milk production.—It was formerly assumed that when dairy cows were fed common well-balanced rations containing plenty of protein and a liberal amount of legume hay, there could be no deficiency in calcium (lime) or in phosphorus, for legume hay is rich in calcium, and protein-rich feeds are in general high in phosphorus. Surprising results have, however, been secured in extensive experiments at the Ohio Station[12] by Forbes, in which high producing cows have been fed such excellent winter rations as alfalfa or clover hay, corn silage, and corn with such high-protein concentrates in addition as wheat bran, cottonseed meal, linseed meal, dried distillers' grains, or gluten feed. On these rations the cows in most instances lost calcium, phosphorus, and also magnesium from their bodies, being able to assimilate and retain so small a portion of the liberal supply in their feed that it was insufficient to meet the requirements in producing the milk. Even when abundant amounts of calcium, or both calcium and phosphorus, were added to the ration in such forms as steamed bone, calcium carbonate, or calcium lactate (a soluble form of calcium), the losses of these mineral constituents from the body continued. The cause of this condition is still a problem. Possibly the milk producing capacity of our dairy cows has been so increased by selective breeding that it exceeds the ability of high yielding cows to assimilate sufficient mineral nutrients from their feed to meet the heavy demand in producing the large flow of milk during the first part of the lactation period. Later on in lactation, or when they are dry, it was found that they are able to build up again the stores of these mineral constituents in their bodies, if fed plenty of good legume hay.

In experiments at the Wisconsin Station[13] by Hart and Steenbock, dairy cows and also milk goats showed greater ability to assimilate calcium from fresh green feed than from dried forage. Also alfalfa hay cured under caps was apparently superior to that exposed to sunlight during the entire curing process. These trials indicate that fresh green forage contains larger amounts of the vitamine which aids in assimilating calcium from the food. In trials by Meigs of the United States Department of Agriculture,[14] the production of cows which had but little pasturage thruout the year was increased in the following lactation period by feeding sodium phosphate when they were dry. (**104, 574**)

These experiments emphasize the necessity of supplying dairy cows with plenty of calcium and phosphorus, especially by the use of well-cured legume hay, not only in the period of high production, but also later on in lactation and when the cows are dry. When legume hay is not

[12]Ohio Buls. 295, 308, and 330; Proceedings Am. Soc. Anim. Prod., 1917-20, pp. 32-40; Jour. Biol. Chem. 52, 1922, pp. 281-315.

[13]Wis. Bul. 323, p. 17; Res. Bul. 49, p. 18; Jour. Biol. Chem.. 53, 1922, pp. 21-30; 54, 1922, pp. 75-89.

[14]U. S. D. A. Bul. 945.

furnished in abundance, it is undoubtedly wise to add calcium and phosphorus in such forms as steamed bone meal, bone flour, bone black, or ground rock phosphate.

These trials indicate, furthermore, that a liberal supply of pasture or other fresh green feed during a good share of the growing season aids materially in securing continued high production, year after year, from dairy cows.

It has been mentioned previously that serious results follow when common salt is withheld from dairy cows for a long period. Hence salt should always be regularly supplied. (653)

150. Vitamines and milk production.—So far as we now know, the usual type of balanced ration recommended for dairy cows, in which there is plenty of good-quality legume hay, will furnish an ample supply of vitamines for the health of the cows, with the possible exception, just pointed out, of the anti-rachitic vitamine, which apparently aids in the assimilation of calcium. Hart and Steenbock have found in trials at the Wisconsin Station[15] that milk from cows on pasture is much richer in the anti-scorbutic vitamine and also somewhat richer in the fat-soluble vitamine than milk produced by cows fed winter rations of hay, silage, and concentrates. These results indicate that the udder has no power of forming these vitamines that are now recognized as so important in proper nutrition, but that these substances are secured from the supplies in the feed and concentrated by the cow in her milk.

Since most of the scientific studies of the factors influencing the production of milk have been conducted with the dairy cow, the discussion of milk production as relating to that animal is continued in Chapters XXI to XXV. The requirements of the mare, ewe, and sow for the production of milk are also treated in the respective chapters of Part III.

III. Wool Production

151. Composition of wool.—Aside from moisture and dirt, "wool" is made up of pure wool fiber and yolk, the latter including the suint and the wool fat. The wool fiber is practically pure protein, and is of the same chemical composition as ordinary hair, but differs in being covered with minute overlapping scales. The suint, chiefly composed of compounds of potassium with organic acids, forms from 15 to 50 per ct. or more of the unwashed fleece, being especially high in Merinos. As suint is soluble in water, most of it is removed by washing the sheep or fleece, and less is present in the wool of sheep exposed to the weather. The fat, often incorrectly called yolk, is a complex mixture of fatty substances, insoluble in water, and may make up 8 to 30 per ct. of the weight of a washed fleece.

152. Requirements for wool production.—Owing to the large amount of protein stored by sheep in their fleece, their ration should contain some-

[15]Wis. Bul. 323, p. 20; information to the authors.

what more protein than rations for cattle or swine at the same stage of maturity. As is shown in the next chapter, this is taken into consideration in the various feeding standards which have been formulated for various classes of animals. With ewes which are either pregnant or suckling lambs, there is a double demand for food protein, which makes a liberal supply especially advisable. Tho the suint of wool is rich in potassium, this constituent is amply supplied by all usual rations.

Experiments by Wolff[16] and Henneberg[17] show that when sheep are fed insufficient food to maintain their weight, the yield of wool is considerably diminished. On the other hand, according to Warington,[18] the production of wool hair and wool fat is practically no greater when a full-grown sheep receives a liberal fattening diet than when it is maintained in ordinary condition. Feeding lambs liberally produces a larger body and consequently a heavier fleece. At the Wisconsin Station[19] Craig found that lambs fed grain from an early age sheared about 1 lb. more of unwashed but practically the same amount of washed wool as those getting no grain until after they were weaned. The early feeding had produced more yolk but no more wool fibre.

The strength of the wool fiber is dependent on the breed, the quality of the individual sheep, and the conditions under which they are reared. Conditions which check the growth of the wool, such as insufficient feed, undue exposure, or sickness, will produce a weak spot in the wool fiber, thus lessening its strength. The feed and care for the flock should therefore be as uniform as possible.

Soil and climate produce marked effects on the characteristics of sheep, as shown by Brown[20] in his study of the evolution of the various English breeds. The rich lowlands of England with their abundant, nutritious grasses produced the heavy-bodied, plethoric Long-wools, the next higher lands with less abundant herbage furnished the Downs and Middle-wools, while the mountains with scanty herbage produced the active, still lighter breeds. Coleman[21] states that the peculiar luster of the Lincoln wool diminishes when these sheep pass to a less congenial soil, and that wool in certain districts of Yorkshire brings a higher price than that of other localities, due to the favorable influence of soil and climate. He further states that limestone soils, otherwise peculiarly suited to sheep, tend to harshness in wool, which renders it less valuable than that from sheep living on clays or gravels.

The various problems relating to the feeding and care of sheep are discussed in detail in Chapters XXX to XXXII.

[16]Landw. Vers. Stat., 1870, p. 57.
[17]Jour. Landw., 12, 1864, p. 48.
[18]Chemistry of the Farm.
[19]Wis. Rpt. 1896.
[20]British Sheep Farming.
[21]Cattle, Sheep, and Pigs of Great Britain.

CHAPTER VII

FEEDING STANDARDS—CALCULATING RATIONS

I. Early Feeding Standards

In the preceding chapters we have considered the functions of the various nutrients in the nourishment of animals and have studied the general requirements for maintenance, growth, fattening, and the production of work, milk, and wool. To guide the farmer in choosing and computing rations for his stock, scientists have put these requirements into definite form thru the drawing up of *feeding standards.* These are tables showing the amount of each class of nutrients which, it is believed, should be provided for the best results in rations for farm animals of the various ages and classes.

At the beginning of the last century almost nothing was known concerning the chemistry of plants and animals. The farmer then gave his stock hay and grain without knowing what there was in this feed that nourished them. But science soon permeated every line of human activity, and agriculture was benefited along with the other arts. Davy, Liebig, Boussingault, Henneberg, Wolff, Lawes and Gilbert, and other great scientists were early laying the foundations for a rational agricultural practice based on chemistry, and animal feeding gained with the rest.

153. Hay equivalents.—The first attempt to express the relative value of different feeding stuffs in a systematic manner was by Thaer[1] of Germany, who in 1810 published a table of hay equivalents with meadow hay as the standard. According to this writer the amounts of various other feeding stuffs required to equal 100 lbs. of meadow hay in feeding value were:

91 lbs. clover hay	417 lbs. rutabagas
91 lbs. alfalfa hay	602 lbs. cabbages
200 lbs. potatoes	625 lbs. mangels

Naturally opinions on feed values varied, and so there were about as many tables of hay equivalents as there were writers on the subject.

154. The first feeding standard.—Chemistry having paved the way, Grouven[2] in 1859 proposed the first feeding standard for farm animals, based on the crude protein, carbohydrates, and fat in feeding stuffs. This, however, was imperfect, since it was based on the total instead of the digestible nutrients.

155. The Wolff feeding standards.—In 1864 Wolff, a famous German scientist, presented the first table of feeding standards based on the

[1]Landwirtschaft, New Ed., 1880, p. 211.

[2]Feeding Standard for Dom. Anim., Expt. Sta. Rec., IV.

digestible nutrients contained in feeds.[3] These set forth the amounts of digestible crude protein, carbohydrates, and fat required daily by the different classes of farm animals. The Wolff standards were brought to the attention of American farmers 10 years later and were further introduced by Armsby's "Manual of Cattle Feeding," which appeared in 1880. The value and importance of these standards were soon recognized, and with their adoption came the first wide-spread effort toward the rational feeding of farm animals. In 1896 the Wolff standards were modified by Lehmann, as scientific trials had then thrown further light on stock feeding.

The numerous feeding experiments which have been carried on since the Wolff-Lehmann standards were presented have given us much more complete knowledge of the nutrients required by the various classes of farm animals than was possessed by these pioneers in the field of animal nutrition. Naturally, recent experiments show that these early standards are in many respects inaccurate. Taking these facts into consideration, later scientists have drawn up other standards which are presented later in this chapter. The Wolff-Lehmann standards are, however, briefly explained first on account of their historical and foundational importance.

156. The Wolff-Lehmann feeding standards.—The Wolff-Lehmann standards are given in full in Appendix Table IV. From this the following examples are taken for purposes of study:

Digestible nutrients required daily by farm animals per 1,000 lbs. live weight

Animal	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Ox, at rest	18	0.7	8.0	0.1	1 : 11.8
Fattening cattle, 1st period	30	2.5	15.0	0.5	1 : 6.5
Cow, yielding 22 lbs. milk	29	2.5	13.0	0.5	1 : 5.7
Horse, at medium work	24	2.0	11.0	0.6	1 : 6.2

The table shows that according to the Wolff-Lehmann standards a 1,000-lb. ox at rest, neither gaining nor losing in weight, requires for 1 day's maintenance 18 lbs. of dry matter, containing the following digestible nutrients: 0.7 lb. crude protein, 8.0 lbs. carbohydrates, and 0.1 lb. fat, with a nutritive ratio of 1:11.8. When the animal is growing, fattening, giving milk, or doing external work, a larger quantity of nutrients must be supplied than for maintenance, as the table shows.

157. Wolff-Lehmann standards now out of date.—Recent experiments have conclusively shown that dairy cows, work horses, and fattening cattle, sheep, and pigs all need considerably less crude protein than is

[3] Mentzel and von Lengerke, Agricultural Calendar.

recommended in these standards. Since protein-rich feeds are usually the highest in price over most of our country, following these standards is usually decidedly uneconomical. Furthermore, in other respects these standards are inaccurate or unsuited to modern American feeding practices and economic conditions. Appreciating the need for accurate, up-to-date standards for the various classes of stock, one of the authors has drawn up the Morrison feeding standards, which are discussed later in this chapter and are given in Appendix Table V. As these standards are based on the many feeding trials carried on in recent years, they furnish much more reliable information on the requirements of the various farm animals than the Wolff-Lehmann standards.

Altho it is advisable in the actual feeding of stock to follow a modern feeding standard, both students and stockmen should, first of all, familiarize themselves with the Wolff-Lehmann standards because of their historical interest and the great help they have been to animal husbandry in the past. Having considered the Wolff-Lehmann standards, one is prepared for the study of the more accurate modern standards discussed later.

II. Calculating Rations for Farm Animals

158. General requirements of satisfactory rations.—The various feeding standards make recommendations only in regard to the amounts of dry matter, of the various nutrients, and, in the case of the Kellner and Armsby standards, of the net energy which the ration should supply. However, the following highly important factors should also be taken into account in computing rations for farm animals.

159. Suitability of feeds.—The feeds selected for any animal should be such that they will not injure its health or the quality of the product yielded. Feeds which are suited to one class of farm animals may not be adapted to others. Again, a given feed may give satisfactory results when combined with certain other feeds, yet in other combinations it may prove unsatisfactory. A few examples of such conditions are furnished in the following:

Cottonseed meal in moderate amount is an excellent feed for cattle, sheep, and horses, yet it is so frequently poisonous to pigs that feeding the meal, as at present prepared, to these animals cannot be advised. (249) While there is always danger from using feeds damaged by mold, such material may often be eaten with impunity by cattle when it would poison horses or sheep. (397) Timothy hay, which is the standard roughage for the horse, is unsatisfactory for the dairy cow, and may cause serious trouble with sheep, due to its constipating effect. (312)

Feeding cows a heavy allowance of ground soybeans produces unduly soft butter, while an excess of cocoanut meal makes the butter too hard. (256, 260) Peanuts and soybeans produce soft lard when forming too large a part of the ration of fattenings pigs. (258)

It is often highly beneficial to add wheat bran or linseed meal to the ration on account of their slightly laxative effect. (218, 254) On the other hand, when animals are already receiving such laxative feeds as silage, pasture grass, and legume hay, the use of large amounts of bran or linseed meal may be unwise.

160. Bulkiness of ration.—We have already seen that at least with the horse and with young ruminants the ration must contain some roughage to distend the digestive tract properly. (106-7) Futhermore, for the best results the proportion of concentrates and roughages in the ration should be regulated according to the kind and class of animal to be fed and the results sought. Cattle, sheep, and horses can be wintered satisfactorily on roughages alone, if of suitable quality. (80, 90) Even brood sows may be maintained partly on legume hay, when not suckling their young. In the rations for growing and fattening animals and those at work or in milk, a considerable part of the ration should consist of concentrates.

The various feeding standards recognize these facts in the amount of dry matter which they prescribe in the rations for the different classes of animals. Obviously, when the requirement of digestible nutrients or of net energy is high compared with the total amount of dry matter advised, the proportion of concentrates in the ration must be large. On the other hand, for the mere maintenance of animals the standards call for a much smaller amount of digestible nutrients or of net energy, compared with the amount of total dry matter.

161. Mineral matter.—In the various feeding standards no statement is made as to the amount or kind of mineral matter required by the different classes of animals, the supposition being that a ration which provides the proper amount of protein and other nutrients will also furnish an adequate supply of mineral matter, with the exception of common salt, which should always be supplied to stock. (100) We have already seen that in some cases, especially with the pig, the mineral supply may be deficient in amount or unbalanced in character in rations which meet the ordinary standards. (95-101, 119, 149) In computing rations the special requirements of the various classes of animals, as set forth in the various chapters of this book, should therefore be kept clearly in mind.

The mineral constituents most apt to be deficient are calcium and phosphorus. When calcium is lacking in rations it may be cheaply supplied in such forms as precipitated calcium carbonate, finely ground limestone, or chalk. Both calcium and phosphorus may be furnished by feeding bone meal, bone flour, bone black, precipitated bone, or even ground rock phosphate.

162. Palatability.—As has already been pointed out (56), the palatability of the ration is an important factor in stimulating digestion and inducing the animals to consume heavy rations. The wise feeder will utilize feeds of low palatability chiefly for such animals as are being merely maintained, and will feed growing and fattening animals, milk

cows, and horses at hard work rations made up, for the most part at least, of well-liked feeds. Some concentrates, such as malt sprouts and dried distillers' grains, which may not be relished when fed alone, are entirely satisfactory if given in mixture with other better-liked feeds. Similarly, such roughages as straw and marsh hay, which are of low palatability, may be given in limited amount even to animals fed for production, a practice widely followed by European farmers. While the maximum gains may be made on rations composed entirely of exceedingly palatable feeds, it should be remembered that one of the chief functions of our domestic animals is to consume and convert into useful products materials which would otherwise be wasted. (2)

163. Variety of feeds.—Skilled feeders usually maintain that a ration composed of a variety of feeds will give better results than when a smaller number are employed, even tho the latter ration supplies the proper amount of protein, carbohydrates, and fat. From the discussions in the preceding chapters, in which it has been pointed out that the protein furnished by certain feeds is unbalanced in composition, it is evident that a larger variety of feeds may, by the law of chance, furnish a better balanced mixture of protein than one or two feeds alone. (93, 118) With these facts in mind it is wise, in choosing supplements for a ration low in protein, to select those which will supply protein from different sources. For example, it is injudicious to use corn by-products, such as corn gluten feed or gluten meal, in balancing the ration of pigs otherwise fed corn only.

With dairy cows, especially in the case of high-producing animals being forced on official test, skilled feeders place emphasis on having variety in the ration, tho this does not imply changes in the ration from day to day. Indeed, sudden changes in kinds of feed are to be avoided. At least with horses and fattening animals, the advantage of a large variety of feeds in the ration does not seem to have been proven, provided the simple ration furnishes the proper amount and kind of nutrients. For example, oats and timothy hay for the horse, and corn and alfalfa hay for fattening steers furnish rations which can scarcely be improved from the standpoint of production and health, tho other combinations may perhaps be cheaper.

164 Cost of the ration.—The most important factor of all, for the farmer who must depend on the profits from his stock for his income, is the cost of the ration. In securing a ration which provides the nutrients called for by the standards and meets the other conditions previously discussed, lies a great opportunity for exercising foresight and business judgment on every farm where animals are fed. The wise farmer-feeder will consider the nutrient requirements of his animals in planning his crop rotations. Thru the use of grain from corn or the sorghums, legume hay, and such cheap succulence as silage from corn or the sorghums, it is possible in most sections of the country to go far toward solving the problem of providing a well-balanced, economical ration. A

AN UNSATISFACTORY AND EXPENSIVE "BALANCED" RATION

This ration of 20 lbs. timothy hay, 3 lbs. ground corn, 2.25 lbs. ground oats, 4 lbs. wheat bran, and 3.5 lbs. linseed meal, meets the standard for a 1,200-lb. cow yielding 30 lbs. of 3.5 per ct. milk. However, timothy hay is a poor roughage for dairy cows, and also the ration is expensive, due to the large amount of costly protein-rich concentrates needed. Cost, 32.1 cents. (From Wisconsin Station.)

A RATION WHICH IS FAIR, BUT LACKS SUCCULENCE

This ration of 24 lbs. red clover hay, 4.25 lbs. ground corn, 2.5 lbs. ground oats, and 2.25 lbs. wheat bran furnishes no more nutrients than the previous one, but it will produce more milk, because clover hay is far superior to timothy hay as a roughage. Cost, 27.3 cents. (From Wisconsin Station.)

AN EXCELLENT AND ECONOMICAL RATION FOR MILK PRODUCTION

This ration of 12 lbs. red clover hay, 36 lbs. corn silage, 4.25 lbs. ground corn, 1.5 lbs. wheat bran, and 2.25 lbs. cottonseed meal is far superior to the two previous ones, for the feeds are all palatable and suitable for dairy cows, and the silage provides succulence. Cost only 27.0 cents, over 5 cents less than the first ration. (From Wisconsin Station.)

PIGS FED AN EFFICIENT BALANCED RATION

This lot of pigs received barley supplemented by whey. They were carried in dry lot, without pasture, from an initial weight of 128 lbs. to an average weight of 225 lbs., and made the most excellent gain of 2.53 lbs. a head daily. See Page 81. (From Wisconsin Station.)

PIGS FED AN INEFFICIENT BUT "BALANCED" RATION

These pigs, fed barley and wheat middlings, without pasture, were just as thrifty at the start as the lot above. However, due to the inefficiency of their ration they gained only 1.27 lbs. a head daily, or only half as much as the others. The chief deficiencies in the ration of barley and middlings are the poor quality of the proteins and the lack of calcium. See Page 653. (From Wisconsin Station.)

simple method of determining which feeds are most economical to use in making up balanced rations for the various classes of stock is described in the following chapter. (191-195)

165. Feeding standards only approximate guides.—In a previous chapter it has been shown that the composition of a given feeding stuff is not fixed, but may be materially influenced by such factors as climate, stage of maturity when harvested, etc. (81) Individual animals also differ from one another in their ability to digest and utilize their feed. (85-6) It should, therefore, be borne in mind that tables of digestible nutrients and likewise feeding standards are but averages and approximations—something far different from the multiplication table or a table of logarithms. They should be regarded as reasonable approximations to great vital facts and principles in the feeding of farm animals.

The allowance of protein set forth in the standards is the minimum amount recommended by the scientists for the best results. Where protein-rich feeds are lower in price than those carbonaceous in character (197), it is often economical to furnish more protein than is called for by the standards. Except in the case of very young animals, it is, however, probably not advisable to feed rations having a nutritive ratio narrower than 1:4 or 1:4.5. Where protein-rich feeds are high in price, it may be economical to feed a wider ration than advised by the standards, tho it is rarely wise to depart far from them.

166. Limitations of balanced rations.—In the preceding chapters it has been shown that other factors, including vitamines (104, 120), mineral matter (95-101, 119), and the right quality of proteins (93, 118, 148), may be just as important in determining the value of rations as the amount of protein, carbohydrates, fat, or net energy. However, owing to the complexity of these new problems in animal feeding and our fragmentary knowledge concerning them as yet, it is impossible to take them into consideration, even in the most modern feeding standards.

That rations balanced mathematically according to the feeding standards may nevertheless be unsatisfactory is shown in a striking manner in experiments which have been carried on by Hart, McCollum, Steenbock, and Humphrey at the Wisconsin Station[4] for the past 15 years. Where the entire roughage fed cows has consisted of straw from the cereals, even tho the ration has been balanced according to the feeding standards by the addition of grains and protein-rich grain by-products, dead or weak, under-sized offspring have resulted. It has been found that these results were chiefly due to the fact that the straws are very low in lime. Where the roughage was legume hay, corn stover, or even timothy hay or marsh hay rich in lime, normal calves resulted. When lime (calcium) was supplied in such forms as wood ashes, ground rock phosphate, or ground limestone, the bad results of the straws were largely corrected. Where wheat grain and wheat by-products formed the concentrates, poor results were secured even with good roughage.

[4]Wis. Res. Buls. 17, 49; Buls. 287, 302.

This may have been due to the unbalanced nature of the proteins of the wheat grain, and perhaps also to the fact that the germs of the wheat grain contain a substance which is somewhat poisonous when wheat is fed in large quantities in such restricted rations as these, tho in the amounts and combinations in which wheat and wheat by-products are usually fed there is no trouble from this substance.

These experiments emphasize the fact that in forming rations, we must consider not only the physiological action of the individual feeds, but also the effect of the combination as it is found in the ration. With this in view the practical feeder and the student alike will attach especial importance to the summaries presented in Part III of the results actually secured with all classes of animals when fed many different rations.

167. Hints on formulating rations.—In computing rations one should have in mind the approximate amounts of roughage and concentrates required per 100 lbs. live weight by the various classes of animals. As will be shown in the experiments reviewed in Part III, the proportion of concentrates and roughages depends first of all on how much it is desired to force the animal; for example, when it is desired to fatten animals rapidly the allowance of concentrates must be considerably larger than when they are fattened more slowly and over a longer period. In a similar manner, the horse at hard work should be given more grain and less roughage than the horse working but little. In general, the following will be helpful as a guide in computing rations:

Mature idle horses and mature cattle and sheep being maintained at constant weight may be fed chiefly or entirely on roughage, unless it is of poor quality, when some grain must be used.

Horses at work should be fed 2 to 2.5 lbs. of feed, (dry roughages and concentrates combined) daily per 100 lbs. live weight, the allowance of concentrates ranging from 0.7 to 1.4 lbs. per 100 lbs. live weight, for horses at medium to hard work. (See Article **530**.)

Dairy cows in milk will eat 2 lbs. of good quality dry roughage daily per 100 lbs. live weight. Silage may be substituted for dry roughage at the rate of 3 lbs. silage for 1 lb. dry roughage. A common rule is to feed 1 lb. hay and 3 lbs. silage daily per 100 lbs. live weight. Sufficient concentrates should be fed in addition to bring the nutrients up to the standard. (See Article **647**.)

Fattening steers should receive 2.1 lbs. or more of concentrates and dry roughage (or the equivalent in silage) daily per 100 lbs. live weight, the allowance of concentrates ranging from less than 1 lb. to 1.7 lbs. or more, per 100 lbs. live weight, depending on the rate of gain desired and the character of the roughage.

Fattening lambs will consume about 1.4 lbs. of dry roughage daily when fed all the grain they will eat, and up to 2.3 lbs. or over when the grain allowance is restricted. Silage may replace a corresponding amount of dry matter in dry roughage.

Swine can make but limited use of dry roughage, except in the case of brood sows not suckling young.

168. Maintenance ration for steers.—Having discussed the general factors which should be considered in computing rations for farm animals, let us now calculate the feed required, according to the Wolff-Lehmann standard, to maintain a 1,000-lb. ox at rest in his stall when neither gaining nor losing in weight. Since it has been shown that mature animals can be maintained largely on roughages (**90**), let us see how nearly field-cured corn stover and oat straw will meet the require-

ments. Since the standard calls for 18 lbs. of dry matter, we will first try quantities of these feeds which supply approximately this amount.

If for the trial ration it is decided to feed 10 lbs. of corn stover and 10 lbs. of oat straw for roughage, then, using the values for digestible nutrients given in Appendix Table III, the calculations for dry matter and digestible nutrients would be as given below:

	In 100 pounds	In 10 pounds
Corn stover, field-cured		
Dry matter	$59.0 \div 100 \times 10 = 5.90$	
Crude protein	$1.4 \div 100 \times 10 = 0.14$	
Carbohydrates	$31.1 \div 100 \times 10 = 3.11$	
Fat	$0.6 \div 100 \times 10 = 0.06$	
Oat straw		
Dry matter	$88.5 \div 100 \times 10 = 8.85$	
Crude protein	$1.0 \div 100 \times 10 = 0.10$	
Carbohydrates	$42.6 \div 100 \times 10 = 4.26$	
Fat	$0.9 \div 100 \times 10 = 0.09$	

Arranging these results in tabular form, we have:

First trial ration for maintaining 1,000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Corn stover, 10 lbs.	5.90	0.14	3.11	0.06	.....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	.....
First trial ration	14.75	0.24	7.37	0.15	1 : 32.2
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1 : 11.8
Excess or deficit	−3.25	−0.46	−0.63	+0.05	.....

This trial ration contains only about one-third the digestible crude protein called for and also falls below the standard in dry matter and carbohydrates. To improve it let us substitute 5 lbs. of clover hay, which is high in protein, for the same weight of corn stover, and add 0.5 lb. of protein-rich linseed meal. We then have:

Second trial ration for maintaining 1,000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Clover hay, 5 lbs.	4.36	0.38	1.96	0.09	.....
Corn stover, 5 lbs.	2.95	0.07	1.56	0.03	.....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	.....
Linseed meal, 0.5 lb.	0.45	0.15	0.16	0.03	.....
Second trial ration	16.61	0.70	7.94	0.24	1 : 12.1
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1 : 11.8
Excess or deficit	−1.39	0.0	−0.06	+0.14	.....

This ration meets the standard with sufficient closeness. It falls below by more than 1 lb. of dry matter, due to the fact that the Wolff-Lehmann standards were devised to cover the common systems of feeding in Europe, where considerable straw or other low grade roughage is commonly included in rations for horses and ruminants. When only such high grade roughages as silage and legume hay are used, rations which supply enough digestible nutrients will fall below the standard requirement in dry matter. Provided the ration furnishes bulk sufficient to distend the digestive tract properly, as in this ration, no further attention need be paid to such a deficit. American rations will usually furnish an excess of fat over the standard, as is the case with this ration. Then the carbohydrates may fall somewhat below the standard as an offset, it being borne in mind that 1 lb. of fat will replace 2.25 lbs. of carbohydrates. (70)

Several devices[5] have been suggested to shorten the work of computing rations, but it seems best in this book to show how to perform the calculations in the simplest and most direct manner. Thru such drill the student will become familiar with the quantity and proportion of the several nutrients in common feeding stuffs and the amount of these required by farm animals according to the standards.

IV. Kellner's Starch Values and Feeding Standards

As has already been pointed out (78-80), the careful and laborious investigations of Kellner, Zuntz, and Armsby have shown that the total quantity of digestible nutrients in a feeding stuff is not necessarily the true measure of its feeding value, as is assumed in the Wolff-Lehmann feeding standards. These investigators have found that, to determine the true net value of any given feeding stuff to the animal, it is necessary to deduct the energy expended in the work of mastication, digestion, and assimilation from the total available energy furnished by the digestible nutrients in the feeding stuff.

169. Kellner's starch values.—As a result of his investigations Kellner formulated feeding standards based on what he called "starch values."[6] He found that on the average 1 lb. of digestible starch fed to the ox in excess of maintenance requirements produced 0.248 lb. of body fat, and other digestible pure carbohydrates had about the same value. Taking 1 lb. of digestible starch as his unit, he found that 1 lb. of digestible pure protein had a starch value of 0.94 lb.; i. e., it would produce 94 per ct. as much body fat as 1 lb. of digestible starch. Further, in oil-bearing seeds and oil meal, in which the ether extract, or so-called "fat," is practically all pure fat, 1 lb. of digestible fat had a starch value of 2.41 lbs., while in roughage, roots, etc., it had a starch value of only

[5]Willard, Kan. Bul. 115; Spillman, Wash. Bul. 48; Rundles, U. S. Dept. Agr. Bul. 637.

[6]Ernähr. Land. Nutztiere, 1907.

1.61 lbs. Fat in cereals and factory and mill by-products had a starch value of 2.12 lbs., nearly as high as in oil-bearing seeds.

Kellner also found that the net nutritive value of certain concentrates, such as grains and seeds, oil cakes, roots, and slaughter-house by-products, was about the same as that obtained when the several pure nutrients in them were fed separately. It was therefore possible to calculate the approximate starch values of such feeds from the amounts of each class of digestible nutrients they contained. However, it was not possible to compute the starch values of feeds high in fiber with any degree of exactness whatsoever. From the few typical feeds which he actually studied in respiration experiments, Kellner found that with such feeds it was necessary to make deductions from the starch values computed as before, ranging all the way from 5 to 30 per ct. with mill and factory by-products and from 50 to 70 per ct. with straw, to get their true starch values. By making arbitrary deductions in this manner he computed the starch values for a long list of feeding stuffs. Owing to the great amount of labor involved, he determined the starch values by actual experiment for but sixteen feeds. Moreover, he ascertained the starch values for these feeds only when fed in a moderate ration to steers. As will be pointed out later, the values for other classes of stock may differ considerably from these.[7] We must therefore regard these starch values as approximations which are helpful until further data are secured.

170. Kellner's feeding standards.—Kellner then formulated feeding standards for the various classes of animals in which the requirements are expressed in dry matter, digestible protein, and starch values. For example, his standard for the maintenance of the mature steer per 1,000 lbs. live weight calls for 15 to 21 lbs. dry matter, 0.6 to 0.8 lb. digestible protein, and 6.0 lbs. starch values.

Fraps of the Texas Station[8] has computed in a manner similar to that of Kellner what he terms "productive values" of feeds. These are the amounts of body fat which it is estimated 100 lbs. of various feeds will produce when fed in addition to a maintenance ration. Neither the Kellner starch values and feeding standards nor the Fraps productive values are given here in detail, but instead Armsby's recently revised tables of net energy values and of feeding standards, which are chiefly used in this country by those desiring to compute rations according to the net energy system.

V. The Armsby Energy Values and Feeding Standards

171. The Armsby energy values.—With the first and only respiration calorimeter used in the study of farm animals in America, Armsby determined at the Pennsylvania Station[9] the net energy values for

[7]Eckles, Mo. Res. Bul. 7; Woods, Jour. Agr. Sci., 5, 1914, p. 248.

[8]Tex. Buls. 185, 203.

[9]U. S. Dept. Agr., Bur. Anim. Indus., Buls. 51, 74, 101; Farmers' Bul. 346; Dept. Bul. 459; The Nutrition of Farm Animals, 1917.

8 typical feeds and 2 concentrate mixtures. He then used these values and the starch values obtained by Kellner as the basis for estimating the losses of energy in the mastication, digestion, and assimilation of other feeds. By special permission of the authors of this volume, he then computed from the average content of digestible nutrients of the various feeds shown in Appendix Table III, the net energy values of the most important American feeds. These net energy values are primarily for ruminants. As pointed out later, few such data are available for horses or swine. Some of the net energy values for ruminants are given in the following table and a more extensive list in Appendix Table VI.

Net energy values in 100 lbs. of various feeding stuffs

Feeding stuffs	Total dry matter	Digestible crude protein	Digestible true protein	Net energy value
Grains	Lbs.	Lbs.	Lbs.	Therms
Barley	90.7	9.0	8.3	89.94
Corn, dent	89.5	7.5	7.0	89.16
Corn-and-cob meal	89.6	6.1	5.7	75.80
Oats	90.8	9.7	8.7	67.56
Peas, field	90.8	19.0	16.6	78.72
Rye	90.6	9.9	9.0	93.71
Wheat	89.8	9.2	8.1	91.82
By-products				
Brewers' grains, dried	92.5	21.5	20.2	53.38
Brewers' grains, wet	24.1	4.6	4.4	14.53
Buckwheat middlings	88.0	24.6	20.8	72.19
Cottonseed meal, choice	92.5	37.0	35.4	93.46
Distillers' grains, dried, from corn	93.4	22.4	18.3	85.08
Distillers' grains, dried, from rye	92.8	13.6	11.1	56.01
Gluten feed	91.3	21.6	20.1	80.72
Gluten meal	90.9	30.2	28.1	84.15
Linseed meal, old process	90.9	30.2	28.5	88.91
Malt sprouts	92.4	20.3	12.5	72.72
Rye bran	88.6	12.2	10.5	79.35
Skim milk, centrifugal	9.9	3.6	3.6	14.31
Sugar beet pulp, wet	9.3	0.5	0.5	8.99
Tankage, over 60 per cent protein	92.6	58.7	55.6	93.04
Wheat bran	89.9	12.5	10.8	53.00
Wheat middlings, flour	89.3	15.7	14.0	75.02
Wheat middlings, standard	89.6	13.4	12.0	59.10
Dried roughage				
Alfalfa hay	91.4	10.6	7.1	34.23
Clover, crimson	89.4	9.7	6.9	36.21
Clover, red	87.1	7.6	4.9	38.68
Cowpea hay	90.3	13.1	9.2	37.59
Corn fodder, medium dry	81.7	3.0	2.3	43.94
Corn stover, medium dry	81.0	2.1	1.6	31.62
Millet hay, Hungarian	85.7	5.0	3.9	46.96
Mixed timothy and clover hay	87.8	5.3	3.2	41.07
Oat straw	88.5	1.0	0.8	34.81
Red top hay	90.2	4.6	3.9	51.22
Rye straw	92.9	0.7	0.5	17.59
Soybean hay	91.4	11.7	8.8	44.03
Timothy hay	88.4	3.0	2.2	43.02
Wheat straw	91.6	0.7	0.3	7.22
Green fodder and silage				
Alfalfa, in bloom	25.9	3.3	1.8	11.50
Clover, crimson	17.4	2.3	1.6	10.83
Clover, red	26.2	2.7	1.7	15.87
Corn fodder, dent	23.1	1.0	0.8	14.60
Corn silage, well matured	26.3	1.1	0.9	15.90
Millet, Hungarian	27.6	1.9	1.1	17.24
Oat fodder	26.1	2.3	2.0	14.06
Rape	16.7	2.6	1.7	13.07
Timothy, in bloom	32.1	1.3	0.8	18.89
Roots and tubers				
Carrots	11.7	0.9	0.5	9.21
Mangels	9.4	0.8	0.1	5.68
Potatoes	21.2	1.1	0.1	18.27
Rutabagas	10.9	1.0	0.3	8.46
Turnips	9.5	1.0	0.4	6.16

The last column of the table does not show the total energy in the digestible portion of 100 lbs. of the various feeding stuffs, but only the net energy; i, e., that portion which is finally available to the animal after deducting the losses occurring thru mastication, digestion and assimilation. He expresses the net energy in therms in place of Kellner's

starch values. (78) The second column gives the digestible crude protein, as shown in Appendix Table III of this book, and the third column the digestible true protein as estimated by Armsby from the crude protein and Kellner's data.

Of the feeds listed, rye has the highest net energy value, 93.71 therms per 100 lbs. Due to the large amount of fiber contained in the hulls, the net energy value of oats is only 67.56 therms per 100 lbs. The dry roughages furnish much less net energy than the concentrates, wheat straw having a value of only 7.22 therms per 100 lbs.

172. The Armsby standards for maintenance.—The following table sets forth the maintenance requirements of horses, cattle, sheep, and swine, as presented by Armsby.[10]

Armsby's maintenance requirements, per head daily

Live weight	Cattle		Horses	
	Digestible protein	Net energy	Digestible protein	Net energy
Lbs.	Lbs.	Therms	Lbs.	Therms
150	0.08	1.69	0.08	1.16
250	0.13	2.38	0.13	1.63
500	0.25	3.78	0.25	2.58
750	0.38	4.95	0.38	3.39
1000	0.50	6.00	0.50	4.10
1250	0.63	6.96	0.63	4.76
1500	0.75	7.86	0.75	5.37

Live weight	Sheep		Swine	
	Digestible protein	Net energy	Digestible protein	Net energy
Lbs.	Lbs.	Therms	Lbs.	Therms
20	0.011	0.27	0.010	0.43
40	0.022	0.43	0.019	0.68
60	0.033	0.56	0.029	0.89
80	0.044	0.68	0.038	1.08
100	0.055	0.79	0.048	1.25
120	0.066	0.89	0.058	1.41
140	0.077	0.99	0.067	1.56
160	0.088	1.09	0.077	1.71
180	0.099	1.17	0.086	1.85
200	0.110	1.25	0.096	1.99

The requirements for protein given in these tables depend on the live weight. For example, the protein requirement for maintaining a 500-lb. steer, neither gaining nor losing in weight, is 0.25 lb., and that for a 1,000-lb. steer just twice as much. As has been pointed out (**90**), theoretically the heat requirements for maintenance depend on body surface instead of body weight, and Armsby hence computed the energy requirements on this basis. Therefore, he did not recommend twice as much net energy for the 1,000-lb. steer as for the 500-lb. steer. However, he found in later trials that the actual maintenance requirement of different steers agreed as well with their live weights as with their body surfaces.

[10]**The Nutrition of Farm Animals, pp. 711-714.**

173. Standards for growing animals.—The requirements for growing cattle, sheep, and swine, according to Armsby, are as follows. No data have as yet been given for horses. These figures include the amounts of digestible protein and net energy required for mere maintenance.

Requirements for growth, including maintenance, per head daily

(1) Cattle

Age	Beef breeds			Dairy breeds		
	Live weight	Digestible protein	Net energy	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
1	125	0.70	3.7	100	0.40	3.1
2	175	0.85	4.2	135	0.45	3.4
3	200	0.90	4.2	165	0.55	3.6
6	350	1.15	5.0	275	0.70	4.1
9	450	1.25	5.7	325	0.75	4.4
12	550	1.40	6.5	400	0.80	5.1
18	750	1.40	8.2	550	0.85	6.4
24	900	1.30	9.3	700	0.85	7.6
30	1000	1.30	9.9	800	0.85	8.2

(2) Sheep

Age	Wool breeds			Mutton breeds		
	Live weight	Digestible protein	Net energy	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
3	37	0.13	0.78	40	0.22	0.84
6	65	0.18	0.95	72	0.30	1.03
9	82	0.17	1.06	98	0.28	1.22
12	90	0.15	1.12	115	0.25	1.36
18	100	0.12	1.19	150	0.22	1.64

(3) Swine

Age	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms
1	15	0.10	0.65
2	30	0.20	1.00
3	52	0.30	1.38
6	118	0.40	2.28
9	183	0.50	3.06
12	250	0.55	3.80

These tables show that a 6-months-old beef calf, weighing 350 lbs., requires 1.15 lbs. digestible protein and 5.0 therms net energy daily. When it reaches the weight of 1,000 lbs., or three times as much, it requires but 0.15 lb. more digestible protein and only about twice as much net energy. This relative lessening in feed requirement as the animal grows older is due to the fact that it is gaining less rapidly per unit of body weight and that as it becomes larger it requires relatively less for maintenance, as has been pointed out before. (**90, 114**)

174. Milk cows, fattening animals, and work horses.—The requirements for milk cows, fattening animals, and work horses, according to Armsby, are as follows:

Milk production—Add to maintenance requirement daily for each pound of milk produced

	Digestible protein	Net energy
	Lbs.	Therms
For each lb. of 2.5 per ct. milk	0.041	0.190
For each lb. of 3.0 per ct. milk	0.043	0.214
For each lb. of 3.5 per ct. milk	0.045	0.238
For each lb. of 4.0 per ct. milk	0.049	0.265
For each lb. of 4.5 per ct. milk	0.052	0.291
For each lb. of 5.0 per ct. milk	0.055	0.315
For each lb. of 5.5 per ct. milk	0.058	0.338
For each lb. of 6.0 per ct. milk	0.061	0.361
For each lb. of 6.5 per ct. milk	0.064	0.385
For each lb. of 7.0 per ct. milk	0.068	0.408

Fattening all species of animals with no considerable growth. Daily in addition to the maintenance requirement

	Per pound of increase in live weight		Digestible protein per 1,000 lbs live weight
	Digestible protein	Net energy	
	Lbs.	Therms	Lbs.
In early stages	0.15	2.50	0.25–0.75
In late stages	0.05	4.00	
Average for entire fattening period	0.10	3.25	

Work horses, daily per 1,000 lbs. live weight

	Digestible protein	Net energy
	Lbs.	Therms
Full work—8 hours per day	2.0	18.2
Half work—4 hours per day	1.4	11.1
One-fourth work—2 hours per day	1.0	7.6

In computing rations for horses by the Armsby standard the net energy values for horses, given in a later chapter (**447**), should be used for the feeds for which such values are available.

175. Fattening lambs.—Bull and Emmett of the Illinois Station[11] have made a critical and comprehensive study of the American investigations in fattening lambs, covering trials in which 265 lots of lambs, aggregating 5,127 animals, were fed. From the results secured in these trials, they give the following as the approximate minimum requirements of digestible crude protein and net energy per 1,000 lbs. live weight.

[11]Ill. Bul. 166.

Bull-Emmett standards for fattening lambs

Weight	Per 1,000 lbs. live weight	
	Digestible crude protein	Net energy value
	Lbs.	Therms
Lambs weighing 50-70 lbs.	3.1–3.3	17–19
Lambs weighing 70-90 lbs.	2.5–2.8	18–20
Lambs weighing 90-110 lbs.	2.2–2.4	17–20
Lambs weighing 110-150 lbs.	1.4–1.9	16–19

It will be noted that the requirements for protein are expressed in terms of crude protein instead of true protein, as in the Armsby standards. Bull and Emmett state that the figures for lambs weighing 110 to 150 lbs. are only approximations, owing to the small amount of data available for animals of these weights. It will be noted that as the lambs become more mature the amount of protein required per 1,000 lbs. live weight grows less.

176. Ration for maintaining the steer.—To illustrate the method of using the Armsby standards and table of net energy values, let us compute a ration for maintaining a mature steer weighing 1,000 lbs., when neither gaining nor losing weight, assuming that there are available corn stover, oat straw, dent corn, and cottonseed meal. According to the standard, an animal of this weight requires 0.5 lb. digestible protein and 6.0 therms of net energy. As corn stover and oat straw are much cheaper than the concentrates, let us first see how nearly a ration of these roughages alone will meet the requirements. Suppose that we select for a trial ration 10 lbs. of corn stover and 8 lbs. of oat straw. This ration will furnish the dry matter, digestible protein and net energy shown in the table.

First trial ration for maintaining 1,000-lb. steer

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs.	8.10	0.16	3.16
Oat straw, 8 lbs.	7.08	0.06	2.78
First trial ration	15.18	0.22	5.94
Standard requirement	....	0.50	6.00
Excess or deficit	....	−0.28	−0.06

This ration furnishes enough net energy but is deficient in digestible protein. Corn, which is high in net energy but low in protein, will not improve the ration, while cottonseed meal, which is rich in protein, will make up the deficiency. Let us therefore substitute 1 lb. of choice cottonseed meal for 2 lbs. of oat straw. We then have:

Second trial ration for maintaining 1,000-lb. steer

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs.	8.10	0.16	3.16
Oat straw, 6 lbs.	5.31	0.05	2.09
Cottonseed meal, 1.0 lb.	0.92	0.35	0.93
Second trial ration	14.33	0.56	6.18
Standard requirement	....	.50	6.00
Excess or deficit	....	+0.06	+0.18

This ration agrees closely with the standard in digestible protein and net energy value. Thus, according to the Armsby standard, a satisfactory ration for maintaining a 1,000-lb. steer may be composed of 10 lbs. corn stover, 6 lbs. oat straw and 1 lb. choice cottonseed meal.

177. Discussion of the net energy systems.—The determination of the net energy values of feeding stuffs is an important advancement in our knowledge of the values of different feeds for productive purposes. Owing to the immense amount of labor involved in each such determination, data of this kind can be secured but slowly. In the many years he carried on his very painstaking investigations by means of the respiration calorimeter Armsby was able to complete studies of only 10 individual feeds or concentrate mixtures, several determinations having, of course, been made on each. Thus, the actual net energy values of but few feeds have been determined by Armsby, Kellner, and others. While these values are helpful in estimating the probable net energy values of other feeds not yet tested, such computed results are but approximations. For example, in his earlier table of energy values, Armsby gave a net energy value of 33.56 therms for timothy hay containing 86.8 per ct. dry matter. This value was computed from Kellner's data. After conducting several respiration experiments in which the actual net value was determined, Armsby found that timothy hay containing the same amount of dry matter had a net energy value of 42.20 therms, or 25.7 per ct. more than his former figure.

Even for the feeds on which experiments have been conducted, the values are far from exact. Not only do different samples of a given feeding-stuff vary in composition (81), but the trials show that the ability to utilize feed, even by animals of the same kind, age, and condition, may vary to a greater or less extent. Moreover, the results of both Kellner and Armsby were secured only with steers. Eckles of the Missouri Station[12] has found these values too low when applied to the dairy cow, and Woods[13] of Cambridge University, England, has shown that they are too high for the ox fed a heavy fattening ration.

Zuntz[14] states that with the horse and pig only a small portion of

[12]Mo. Res. Bul. 7. [13]Jour. Sci., 5, 1914, p. 248.

[14]Inter. Inst. Agr., Monthly Bul., 5, 1914, No. 4, pp. 435, 446.

the starch in feeds ferments in the digestive tract. On the other hand, in cattle upwards of 10 per ct. of the heat value of the digested food is lost in methan gas and about 7 per ct. is wasted, so far as productive purposes are concerned, in the heat produced in the fermentations. (79-80) Accordingly, with horses and pigs starch will have a higher value compared with fat than in the case of ruminants.

It should also be remembered that the Armsby standards are based on only the digestible *protein* in various feeds, not including the amids. It has previously been pointed out that recent investigations make it appear preferable to compute balanced rations on the basis of the digestible *crude* protein the different feeds contain. (94)

We must thus regard the present net energy values of feeding stuffs, not as exact measures of their value for all classes of animals, but as approximations which are most helpful in teaching great principles in the feeding of live stock.

From the foregoing discussion the wise feeder will see the importance of studying carefully the results actually secured with different combinations of feed when fed to the various classes of animals, as presented in detail in the respective chapters of Part III.

VI. The Scandinavian Feed-Unit System

A system of feed equivalents, based mainly on the experiments with milk cows and swine by Fjord and his successors in Denmark and the investigations of Hansson in Sweden, has been adopted in Denmark and other Scandinavian countries, especially by the cow-testing associations, for measuring the relative values of different feeds and the efficiency of cows. This system is also used to a less extent with pigs and other classes of animals. For the reasons pointed out later, it has never been used to any large extent in this country.

178. The feed unit.—The feed unit of the Danish associations is 1 lb. of standard grain feed, such as corn and barley, or their equivalents in feeding value. In Sweden it is one kilo (2.2 lbs.) of barley or its equal in other feeds. All feeding-stuffs are reduced to this standard in calculating the feed consumption of the animal. The amounts of various feeds required to equal 1 feed unit are shown in the following table.

The table shows that corn, wheat, rye, barley, hominy feed, the dry matter in roots, etc., are all considered to have about the same value for the dairy cow, 1 lb. equaling 1 feed unit. On this basis it requires 1.1 lbs. of wheat bran or oats, or 1.5 to 3 lbs. of alfalfa or clover hay to equal 1 unit. Cottonseed meal, linseed meal, dried distillers' grains, gluten feed, and soybeans are rated at a higher value than the same weight of corn or wheat, less than a pound of these concentrates being required for a feed unit.

*Amount of different feeds required to equal one feed unit**

Feed	Feed required to equal 1 unit	
	Average	Range
For dairy cows	Lbs.	Lbs.
Concentrates		
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, oat shorts, peas, molasses—beet pulp, dry matter in roots	1.0	.....
Cottonseed meal	0.8	.....
Oil meal, dried distillers' grains, gluten feed, soybeans	0.9	.....
Wheat bran, oats, dried beet pulp, barley feed, malt sprouts	1.1	.....
Alfalfa meal, alfalfa-molasses feeds	1.2	.....
Hay and straw		
Alfalfa hay, clover hay	2.0	1.5–3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red top hay	2.5	2.0–3.0
Timothy hay, prairie hay, sorghum hay	3.0	2.5–3.5
Corn stover, stalks or fodder, marsh hay, cut straw	4.0	3.5–6.0
Soiling crops, silage and other succulent feeds		
Green alfalfa	7.0	6.0–8.0
Green corn, sorghum, clover, peas and oats, cannery refuse	8.0	7.0–10.0
Alfalfa silage	5.0	.....
Corn silage, pea vine silage	6.0	5.0–7.0
Wet brewers' grains	4.0	.....
Potatoes, skim milk, buttermilk	6.0	.....
Sugar beets	7.0	.....
Carrots	8.0	.....
Rutabagas	9.0	8.0–10.0
Field beets, green rape	10.0	.....
Sugar beet leaves and tops, whey	12.0	.....
Turnips, mangels, fresh beet pulp	12.5	10.0–15.0
The value of pasture is generally placed at 8 to 10 units per day, on the average, varying with kind and condition.		
For pigs		
Barley, wheat, rye, peas, wheat middlings, linseed cake, soybean cake, peanut cake, corn germ meal	1.0	.....
Meat meal	0.6	.....
Corn, corn gluten feed	0.95	.....
Dried beet pulp, molasses-beet pulp	1.3	.....
Skim milk, buttermilk	6.0	.....
Whey	12.0	.....
Potatoes	3.6	.....
Sugar beets	4.0	.....
Mangels	7.2–9.0	.....
Rutabagas	8.5	.....
For horses		
Barley, molasses, dried potato flakes	1.0	.....
Corn	0.95–1.0	.....
Dried beet pulp, dry matter in roots	1.1	.....
Oats, wheat bran	1.2	.....

*The values for dairy cows are those computed by Woll for American feeding stuffs, given in Wis. Cir. 37. The values for swine and horses are those given by Hansson in his book, *Utfodringslära*, and in *Fühling's Landw. Zeit.*, 65, 1916, p. 314.

The feed-unit values for dairy cows are not true expressions of net energy, for feeds rich in protein are given a higher value than feeds low in protein which furnish the same amount of net energy. For example, in the feed-unit system, only 0.9 lb. of linseed meal, gluten feed, or dried distillers' grains is required to equal 1 feed unit. Yet, according to Armsby the net energy value of these feeds is lower than that of corn. Again, the energy value of timothy hay is even higher than that of clover or alfalfa hay, but in the feed-unit system timothy hay is rated 50 per ct. below the legume hays. When added to rations deficient in protein, protein-rich feeds are worth more than those which are low in protein but yet furnish an equal amount of net energy. However, as

has been pointed out (**63, 92**), when the protein supply in the ration is already adequate, any additional amount of this nutrient is broken down in the body, the nitrogenous portion being excreted in the urine, and only the remainder utilized for the formation of the fat and carbohydrates in flesh or milk, for body fuel, or for the production of work. In all such cases protein will have a value corresponding only to the amount of net energy it furnishes. Over large sections of our country protein-rich feeds are cheaper than those high in carbohydrates. In the West with its abundant and cheap alfalfa hay, and in the South with its low-priced cottonseed meal, it is often necessary to add carbonaceous feeds rather than protein-rich concentrates to balance the usual rations. Thus the feed-unit system does not furnish a safe guide by which the farmer can determine the value of feeds under all conditions. The worth of a given feed to him will depend on the other feeding-stuffs with which it is to be combined. In some instances protein-rich feeds will be worth the most, and in others, those which are high in carbohydrates. The feed-unit system has been evolved in a comparatively small region, where similar crops are grown on the different farms and the price of purchased feeds does not vary widely thruout the entire district, hence this difficulty has not arisen there. No arbitrary values for feeding-stuffs, expressed in terms of money or other fixed units, can be devised which will hold good under widely differing conditions.

179. Measuring economy of production in feed units.—The chief value of the feed-unit system for dairymen in any given region is that it furnishes a simple means of comparing the feed consumption and the milk and fat production of different cows, as is shown in the following:

If during a month a cow has consumed 240 lbs. of hay, 750 lbs. of silage, 60 lbs. each of barley and ground corn, and 90 lbs. of linseed oil meal, the calculation based on the valuation table would be as follows:

Feed consumed		Lbs. for 1 unit		Feed units
240 lbs. hay	÷	2.5	=	96
750 lbs. silage	÷	6.0	=	125
120 lbs. corn and barley	÷	1.0	=	120
90 lbs. oil meal	÷	0.9	=	100
Total feed units			=	441

It is shown that the cow consumed 441 feed units during the month. If in that time she yielded 850 lbs. of milk, containing 30.6 lbs. of fat, each 100 feed units produced $\frac{850}{4.41}$ = 193 lbs. of milk, containing $\frac{30.6}{4.41}$ = 6.9 lbs. butter fat. If the fat brought 30 cents per lb., 100 feed units would return 6.9x\$0.30=\$2.07.

180. The Swedish cow testing associations.—The method of using the feed-unit system to compare the relative efficiency of different herds is illustrated by data secured in the Swedish cow testing associations. During the year 1906-7, the cows in 96 associations consumed on the average 5,280 feed-units, made up of the following: oil cakes, 856 units;

grain and bran, 708 units; roots and beet pulp, 1,166 units; hay and straw, 1,256 units; and soiling crops and pasture, 1,294 units. The average production of milk for the year was 7,429 lbs. and of butter fat 239.9 lbs. For each 100 feed units consumed, the cows produced on the average 140.7 lbs. of milk, containing 4.5 lbs. butter fat.

The cows in the association having the best returns were fed 5,733 feed units per cow for the year and produced on the average 8,650 lbs. milk, containing 295.2 lbs. butter fat. The cows in the poorest association received an average of only 4,920 feed units, and their average yield was but 6,261 lbs. milk and 200.0 lbs. butter fat. The cows in the best association produced 5.1 lbs. butter fat from 100 feed units, while those in the poorest association, which were fed less liberally and probably also were of lower productive capacity, yielded only 4.1 lbs. butter fat for each 100 feed units consumed. The best herds thus produced 1 lb. more butter fat from 100 feed units consumed than did the poorer herds—a difference of over 24 per ct. in favor of the heavier feeding and better cows.

These results show the manner in which Scandinavians have utilized the feed-unit system for comparing individual cows, herds, and associations to the great betterment of their dairy industry. The same comparisons can be made by means of the Armsby system of net-energy values. Except where the rations fed to different animals vary widely in proportion of concentrates to roughages, a fair comparison may also be made by using the total digestible nutrients in the ration, as given for each feed in Appendix Table III.

181. The feed-unit standard for dairy cows.—Hansson[15] has proposed the following standard for dairy cows, according to the feed unit system:

Hansson feeding standard for dairy cows

	Dry matter Lbs.	Digestible protein Lbs.	Feed units
Maintenance of 1,100-lb. cow	17.6–24.2	0.72	7.3
1,100-lb. cow yielding 11 lbs. milk	19.8–28.7	1.10	11.0
1,100-lb. cow yielding 22 lbs. milk	22.0–33.1	1.65	14.6
1,100-lb. cow yielding 33 lbs. milk	24.2–35.3	2.20	18.3
1,100-lb. cow yielding 44 lbs. milk	26.4–37.4	2.76	22.0

This standard fails to take into consideration the fact that the feed requirements of a dairy cow depend not only on the *amount* of milk produced, but also on the *quality* of the milk; i. e., its richness in fat. It is therefore less accurate when applied to animals of different breeds than the modern American standards. (**174, 182, 183, 184, 185, 189**)

VII. American Standards for Dairy Cows

182. The Haecker standard. —As the result of long years of intimate study with a high-grade working dairy herd at the Minnesota Station,[16]

[15]Utfodringslära, 1916, p. 707. [16]Minn. Buls. 71, 79, 140.

Haecker made an important advance in the formulation of rations for the dairy cow. He was the first to show that the nutrients required for her nourishment should vary not only with the quantity of milk yielded, as was taught in the Wolff-Lehmann, the Kellner and the feed-unit standards, but also with the quality of the product. The allowance of crude protein recommended is also considerably lower than advised in the original Wolff-Lehmann standards. Haecker's recommendations are given in comparison with other modern standards for dairy cows in the table on Page 133. Haecker expressed his standards in terms of digestible crude protein, digestible carbohydrates, and digestible fat, but in this table the recommendations have been simplified and are given in terms merely of digestible crude protein and total digestible nutrients, for as we have already learned in previous chapters, carbohydrates and fat in general perform the same functions in the body. Likewise, when more protein is supplied than is needed for the repair of the body tissues and the formation of the protein in the milk, any additional amount may be used for the same purposes as the carbohydrates and fat.

This table shows that, according to Haecker, the 1,000-lb. cow requires 0.700 lb. digestible crude protein and 7.925 lbs. total digestible nutrients merely to maintain her body, independent of the requirements for the production of milk. The maintenance requirements of cows of other live weights are proportional to their weights. For example, to find the maintenance requirements for a 1,200-lb. cow, these figures are multiplied by 1.2. The table also gives the amounts of digestible crude protein and total digestible nutrients required for the production of a pound of milk of the various fat contents, after the needs for mere body maintenance have been met. For instance, a cow requires 0.047 lb. digestible crude protein and 0.284 lb. total digestible nutrients in addition to the maintenance requirements for each pound of 3.5 per ct. milk she produces. If her milk contains 5 per ct. fat, the amount of nutrients needed for each pound of milk produced is much larger, being 0.060 lb. digestible crude protein and 0.398 lb. total digestible nutrients. By multiplying the requirements for each pound of milk by the number of pounds yielded daily and adding the result to the requirements for maintenance, the total amounts of nutrients needed by an individual cow are readily found.

183. The Woll-Humphrey standard.—At the Wisconsin Station Woll and Humphrey prepared convenient tables showing the feed requirements of cows of different weights and producing various amounts of butter fat per day. For example, the requirements of the 1,000-lb. cow producing 1 lb. of butter fat daily, according to these tables, are 22.3 lbs. dry matter, 2.02 lbs. digestible crude protein, and 15.4 lbs. total digestible nutrients. For the same cow yielding 1.5 lbs. fat daily, 27.3 lbs. dry matter, 2.86 lbs. digestible crude protein, and 19.2 lbs. total digestible nutrients are recommended.[17] This system gives only ap-

[17] Table as revised by Humphrey, unpublished data.

proximate results, for a cow requires considerably more nutrients to produce 1 lb. of butter fat in milk low in fat than if her milk is high in fat.

184. The Savage standard.—From trials at the New York (Cornell) Station[18] Savage concludes that for maximum production the nutritive ratio of rations for dairy cows should not be wider than 1:6. He has accordingly modified the Haecker standard by increasing the protein requirement per pound of milk by from 18 to 20 per ct. His standard is also simplified by being stated in terms of dry matter, digestible crude protein, and total digestible nutrients. The requirements according to this standard are shown in the table on this page.

185. The Eckles standard.—From experiments at the Missouri Station[19] and from the work of Savage and Armsby, Eckles formulated a tentative standard according to the Armsby system, showing the requirements of cows producing milk containing various percentages of fat. He points out that these are but approximations, for the following reasons: The digestion coefficients in use, which have been chiefly obtained with steers and sheep, are too high for feeds fed in heavy rations to dairy cows. This is, however, more than offset by the fact that the cow is able to utilize the nutrients she actually digests more efficiently in milk production than the steer or sheep does in formation of flesh. Hence the net energy values given by Armsby are too low when applied to milk production. More recently Armsby prepared complete standards himself on the net energy basis for dairy cows producing milk containing various percentages of fat. These standards, which are given on Page 125, are compared with the Eckles standards in the following table.

186. Comparison of standards for dairy cows.—In the following table the Haecker, Savage, Eckles, and Armsby standards are brought together for comparison. Haecker's figures have been converted into total digestible nutrients, as in the Savage standard.

Feeding standards for dairy cows compared

	Haecker standard		Savage standard		Eckles standard		Armsby standard	
	Diges'ble crude protein	Total diges'ble nutrients	Diges'ble crude protein	Total diges'ble nutrients	Diges'ble true protein	Net energy	Diges'ble true protein	Net energy
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms
For maintenance of 1,000-lb. cow	0.700	7.925	0.700	7.925	0.500	6.00	0.500	6.00
To allowance for maintenance, add for each lb. milk—								
2.5 per cent milk	0.045	0.254	0.053	0.257	.....	.....	0.041	0.190
3.0 per cent milk	0.047	0.284	0.057	0.287	0.050	0.26	0.043	0.214
3.5 per cent milk	0.049	0.313	0.061	0.319	0.052	0.28	0.045	0.238
4.0 per cent milk	0.054	0.343	0.065	0.350	0.055	0.30	0.049	0.265
4.5 per cent milk	0.057	0.372	0.069	0.379	0.058	0.33	0.052	0.291
5.0 per cent milk	0.060	0.398	0.073	0.405	0.062	0.36	0.055	0.315
5.5 per cent milk	0.064	0.424	0.077	0.431	0.066	0.40	0.058	0.338
6.0 per cent milk	0.067	0.451	0.081	0.457	0.070	0.45	0.061	0.361
6.5 per cent milk	0.072	0.480	0.085	0.484	0.075	0.50	0.064	0.385
7.0 per cent milk	0.074	0.502	0.089	0.508	.....	....	0.068	0.408

The Haecker and Savage standards agree in the requirements for maintenance. Savage's digestible crude protein requirement for pro-

[18]N. Y. (Cornell) Bul. 323. [19]Mo. Res. Bul. 7.

duction is higher in each case, as already pointed out. In total digestible nutrients he agrees very closely with Haecker. As the Eckles and Armsby standards are expressed in digestible true protein (not crude protein) and therms, they can not be compared directly with the standards of Haecker and Savage. We may, however, compare these standards with the others in the following manner: In such a ration as 20 lbs. clover hay, 4 lbs. corn, and 4 lbs. wheat bran, we would find that about one-third of the total digestible crude protein is in amid form (11) and hence not included in Eckles' figure for digestible true protein. With rations including green forage or silage, the proportion of true protein will be still lower. It is evident, then, that if Armsby's figures for true protein were converted into crude protein they would be fully as high as those of Savage's and that Eckles' figures would be even higher, when applied to ordinary rations. As about 1.1 to 1.2 lbs. total digestible nutrients have a net energy value of 1 therm in the ordinary rations used for dairy cows, it will be found on computation that Eckles' standards call for about the same amount of total nutrients as the standards of Haecker and Savage for milk low in fat, but up to one-fifth more for milk high in fat. Armsby's standards advise less nutrients than any of the other standards, requiring from 1 to 3 lbs. less concentrates to balance the ration, depending on the production of the cow, than the Savage or Haecker standards. In a trial by Morrison, Humphrey, and Putney at the Wisconsin Station[20] cows fed enough concentrates to meet the recommendations of the Savage standards produced slightly more milk and fat than when fed only enough concentrates to meet the requirements as stated by Armsby, but milk and fat were produced slightly more economically on the Armsby rations, due to the fact that at that time (1918) concentrates were unusually high in price. (569)

From these results we may conclude that it is necessary to feed dairy cows as much concentrates as are required to meet the recommendations of the Savage or Haecker standards when the object is maximum production, as in the case of cows on official test. It is also economy to feed a liberal concentrate allowance when concentrates are relatively low in price compared with hay and other roughage. On the other hand, when concentrates are expensive compared with roughage, the most economical production, but not the maximum production, can be secured by feeding no more concentrates than are required to meet the recommendations of the Armsby standard. The amount of protein and the proportion of concentrates to feed dairy cows are discussed further in Articles **194, 197-8, 569,** and **645-6.**

VIII. Morrison Feeding Standards

187. Methods of computing rations compared.—In this chapter it has been pointed out that the valuation of feeding stuffs for productive

[20]Wis. Bul. 323, pp. 7-8.

purposes, on the basis of their net energy content, is theoretically more accurate than the Wolff-Lehmann method of comparing them in terms of the digestible nutrients they furnish. Unfortunately, the net-energy values have actually been determined for but a few feeds, and with these only for the fattening ox. For other feeds and other classes of animals, the values which may be computed are but approximations. On the other hand, during the last half-century scores of thousands of analyses of feeding stuffs have been made, as shown in Appendix Table I, and large numbers of digestion experiments have been conducted in which the coefficients of digestibility have been determined, as given in Appendix Table II. Thus the values for digestible nutrients in the various feeding-stuffs, given in Table III, rest on a reasonably secure basis, tho we must remember that different kinds of animals digest somewhat different percentages of feeds, especially of roughages. (85)

The value of a concentrate and of a roughage for productive purposes can not be compared on the basis of the digestible nutrients each furnishes, for in the roughage, containing more fiber, a larger part of the energy in the digested nutrients is used up in the non-productive work of mastication, digestion, and assimilation. (78-80) In the ordinary rations for each class of animals, concentrates and roughages are, however, usually fed in about the same proportions. This tends to lessen any error due to inaccuracy in computing rations according to the Wolff-Lehmann method. Furthermore, the prescription of a definite allowance of dry matter is a check upon the net-energy value of the ration. If a ration contains sufficient digestible nutrients to meet the Wolff-Lehmann standards, but carries an excess of dry matter, obviously too much roughage or concentrates too high in fiber have been used and the net-energy value will consequently be too low. On the other hand, if the content of digestible nutrients satisfies the standard, while the ration does not contain the dry matter called for, it indicates that feeds more concentrated in character than necessary have been used, in which case some roughage or feeds higher in fiber may be substituted till the dry-matter content is brought up to the standard. With this simple check any large error in formulating the ration may be avoided.

188. Necessity for modifying the Wolff-Lehmann standards.—It has already been shown in this chapter that in several instances the original Wolff-Lehmann standards do not set forth the actual requirements of farm animals as revealed by the many experiments which have been carried on since these standards were drawn up. We know, for example, that the allowance of digestible crude protein prescribed is higher than is needed by fattening animals, dairy cows, and work horses. Yet these standards were more commonly employed in this country, except perhaps with the dairy cow, than any other system for formulating rations. Indeed, the authors have found feeders, annually fattening hundreds and even thousands of animals, who were balancing

rations according to the original Wolff-Lehmann standards by the addition of unnecessary amounts of high-priced protein-rich concentrates.

189. Morrison (modified Wolff-Lehmann) standards.—With these facts in mind one of the authors (Morrison) has combined in one standard what appear in his judgment to be the best guides we have at present in the formulation of rations for various classes of animals. To facilitate the computations, the standards, which are given in detail in Appendix Table V, are expressed simply in terms of total dry matter, digestible crude protein, and total digestible nutrients. Realizing that feeding standards are but approximations, in most cases minimum and maximum figures are given for dry matter, digestible crude protein, and total digestible nutrients. Since progressive feeders thruout the country now appreciate the significance of the nutritive ratio of a ration, the approximate upper and lower advisable limits of nutritive ratios for the different classes have been stated. To correspond with these standards a column has been added to Appendix Table III, showing the total digestible nutrients furnished in 100 lbs. of each feed. Likewise, so that one may see at a glance which feeds are high and which are low in protein, compared with carbohydrates and fat, the nutritive ratio for each feed has been computed and is given in the table. With these aids it is hoped that the standards presented may be of real assistance to students and feeders who desire to compute rations substantially in accordance with the Wolff-Lehmann method, while recognizing the results of the later investigations in animal feeding.

The recommendations gathered together in these standards are from many sources. The standards for the dairy cow are based largely upon those formulated by Haecker and Savage. The data for growing, fattening steers are taken mainly from the extensive investigations of Haecker.[21] The figures for fattening 2-year-old steers and for growing, fattening pigs are based chiefly upon studies made at the Wisconsin Station by Morrison[22] of the feeding experiments carried on at American stations. Those for fattening lambs are computed chiefly from the Bull-Emmett standards, based on their study of American feeding trials, and those for work horses are based upon the investigations of Zuntz and upon American feeding trials. In revising the requirements for the other classes of animals there have been utilized the Kellner and Armsby standards, which have already been discussed, and the extensive standards of Pott[23] of Germany, which are formulated in substantially the same terms as the Wolff-Lehmann standards.

[21]Minn. Bul. 193.

[22]The compilation and computation of data in the study of the pig feeding experiments was chiefly done by Messrs. M. L. Geraldson and J. G. Poynton, students in the Wis. College of Agriculture. Profs. G. Bohstedt and J. M. Fargo of the same College, assisted in the compilation of still other data upon which these standards are based.

[23]Handb. Ernähr. u. Futter., I, 1907, pp. 374-376.

190. Ration for fattening 2-yr.-old steers.—To illustrate the manner of computing rations in accordance with the Morrison standards, let us formulate a ration for fattening 2-yr.-old feeder steers. The steers, averaging 960 lbs. when placed in the feed lot, are to be fed a heavy fattening ration for 150 days so that they will gain 2.4 lbs. per head daily, or more. The Morrison standards for 2-yr.-old steers on full feed are as follows:

Morrison standards for 2-yr.-old steers on full feed (From Appendix Table V)

	Per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Minimum of dig. crude protein	Total dig. nutrients	
	Lbs.	Lbs.	Lbs.	
First 40 to 60 days	22–25	1.8–2.1	16.5–18.5	1:7.0–1:8.0
Second 40 to 60 days	20–23	1.8–2.0	16.0–18.0	1:7.0–1:8.0
Third 40 to 60 days	18–21	1.7–1.9	15.5–17.5	1:7.0–1:8.0

It will be noted that the allowance of dry matter is the largest for the first 40 to 60 days of fattening. During this period the steers are being brought to a full feed of grain and are hence consuming a larger proportion of roughage to concentrates than in the later periods. The amount of total digestible nutrients required per 1,000 lbs. live weight also decreases as the steers fatten, but not so much as does the dry matter. The minimum amount of digestible crude protein advised for the first period is 1.9 to 2.2 lbs. per 1,000 lbs. live weight. The larger amount will probably tend to slightly more rapid fattening than the lower figure, but, as is pointed out later, may be less economical than the lesser amount. (**197**)

On comparing these standards, which are based on the results of American feeding trials, with the original Wolff-Lehmann standards, it is seen that the minimum allowance of digestible crude protein advised is considerably lower than in the original standards. The dry matter is also materially lower, for fattening steers fed roughage of good quality, as is commonly done in this country, will not consume as much dry matter as set forth in the original Wolff-Lehmann standards.

In computing rations for these steers, the most accurate way is to figure out the rations on the basis of the average live weight of the steers during each period of fattening. If the steers weigh 960 lbs. when placed on feed and gain 2.4 lbs. per head daily, their average weight for the first 50 days will be 1,020 lbs.; for the second 50 days, 1,140 lbs.; and for the last 50 days, 1,260 lbs. Computing the standard requirements for each period on this basis we have:

Requirements for given steers at different periods of fattening

	Av. wt. during period	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Lbs.	
First 50 days....	1,020	22.4–25.5	1.84–2.14	16.8–18.9	1 : 7.0–1 : 8.0
Second 50 days....	1,140	22.8–26.2	2.05–2.28	18.2–20.5	1 : 7.0–1 : 8.0
Third 50 days....	1,260	22.7–26.5	2.14–2.39	19.5–22.0	1 : 7.0–1 : 8.0

Owing to the greater weight of the cattle in the last periods, tho they require less total digestible nutrients per 1,000 lbs. live weight, the requirements per steer are slightly greater.

Let us now formulate rations to meet these requirements. The steers are to be fed all the well-matured corn silage and good clover hay they will clean up, morning and night, and shelled corn is to be fed as the chief concentrate, with choice cottonseed meal if needed to balance the ration. As shown later (774), 2-year-old steers full fed on corn will eat 30 to 40 lbs. of corn silage during the first period of fattening and gradually less as fattening progresses. Owing to the palatability of the silage they will usually eat only 3 to 6 lbs. of clover hay. For a trial ration during the first period let us therefore take 35 lbs. of corn silage, 4 lbs. of clover hay, and enough shelled corn to bring the amount of total digestible nutrients up to the standard. As shown in the following table, this will require 11 lbs. of corn:

Trial ration for fattening 2-yr.-old steers, first period

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
Corn silage, 35.0 lbs.....	9.20	0.385	6.20	
Clover hay, 4.0 lbs.....	3.48	0.304	2.04	
Shelled corn, 11.0 lbs.....	9.84	0.825	9.43	
Total.....	22.52	1.514	17.67	1 : 10.7

This ration furnishes sufficient total digestible nutrients and agrees with the standard in dry matter, but falls far short in protein. Let us, therefore, replace some of the corn with cottonseed meal. As we wish these steers to make maximum gains, we will supply somewhat more protein than called for by the lower figure in the standard. Substituting 2.0 lbs. of choice cottonseed meal for the same weight of corn, we will have the ration shown in the first division of the following table. This agrees well with the standard and should produce rapid gains when fed to thrifty feeders.

In the same manner we will formulate rations for the middle and the last periods of fattening, bearing in mind that steers on full feed will eat less roughage and more concentrates as they fatten. Since we wish these steers to reach a high finish, we will increase the protein supply

during the last period to the higher figure given in the standard, 2.52 lbs. per head daily. Arranging the data as before, we will have the rations shown in the table:

Rations for fattening 2-yr.-old steers, for first, second, and third periods

Feeding stuffs	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
First 50 days				
Corn silage, 35.0 lbs.	9.20	0.385	6.20	
Clover hay, 4.0 lbs.	3.48	0.304	2.04	
Shelled corn, 9.5 lbs.	8.50	0.712	8.14	
Cottonseed meal, 1.75 lbs.	1.62	0.648	1.37	
Total	22.80	2.049	17.75	1 : 7.7
Second 50 days				
Corn silage, 28.0 lbs.	7.36	0.308	4.96	
Clover hay, 3.0 lbs.	2.61	0.228	1.53	
Shelled corn, 13.0 lbs.	11.64	0.975	11.14	
Cottonseed meal, 2.0 lbs.	1.85	0.740	1.56	
Total	23.46	2.251	19.19	1 : 7.5
Third 50 days				
Corn silage, 23.0 lbs.	6.05	0.253	4.07	
Clover hay, 3.0 lbs.	2.61	0.228	1.53	
Shelled corn, 16.0 lbs.	14.32	1.200	13.71	
Cottonseed meal, 2.1 lbs.	1.94	0.777	1.64	
Total	24.92	2.458	20.95	1 : 7.5

These rations meet the standards in all particulars and will give good results in practice. (**774**) As is explained later (**197**), when protein-rich feeds are high in price compared with those carbonaceous in character, it may be more economical to supply only as much protein as called for in the lower figures in the standard.

As is discussed later (**198, 199, 716**), when corn is high in price compared with roughages, or when the market does not pay a sufficient premium for well fattened cattle, it will be more profitable to feed much less corn than is included in these rations, which are for steers on full feed. In such cases rations should be computed in accordance with the standards given under Division 2 of the Morrison feeding standards, for "Growing, fattening steers." (Appendix Table V) To meet these standards much less concentrates are required. Tho steers thus fed will not make as large gains nor reach as high finish, under the conditions mentioned they will usually return more profit to the feeder than those full fed on grain.

CHAPTER VIII

ECONOMY IN FEEDING LIVE STOCK

I. Selecting Economical Rations

To secure the largest returns from his farm animals the stockman must, first of all, thoroly understand the fundamental nutrient requirements of the various classes of live stock, which have been discussed in the preceding chapters. He must next study the possibilities of his farm for the production of crops, paying attention to both the probable yields and the value of the various crops for feeding to stock or for selling on the market. It is also necessary to consider the feeding value of the many feeds on the market and compare the prices at which they can be secured. With this knowledge he is in a position to plan his rotations so that from the crops raised, supplemented when it is economical by purchased feeds, well-balanced rations for his stock may be provided at minimum expense. As a rule it will be found wise to raise all needed roughage on the farm. Owing to the increasing demand for the cereal grains for human consumption, it is often economical to sell more or less of the farm-grown grains and replace them with purchased concentrates which economically supplement the feeds raised on the farm.

191. Market prices not guides to value.—On studying the market prices of different feeds it will be evident that the market price is often no index to the value of a feed to the individual stockman. A few examples will illustrate this fact. In the northeastern states timothy hay is generally higher in price than clover hay, tho it is much inferior to clover for all animals except the horse. In the South cottonseed hulls usually cost more than the sum for which an equivalent amount of corn silage, a much more palatable feed, can be produced on the farm. Owing to their popularity, some feeds, such as linseed meal and wheat bran, are often high in price compared with other concentrates which are entirely satisfactory substitutes. At the other extreme, low grade concentrates, such as trashy corn and oat feed, cottonseed feed, and inferior mixed feeds often sell for as much or but slightly less than high grade concentrates of far greater feeding value.

192. How to select feeds for economical rations.—Many attempts have been made to assign a definite money value to 1 lb. of digestible crude protein, digestible carbohydrates, and digestible fat, and then compute the value of different feeds on the basis of the amount of these nutrients they contain, the same as is commonly done in arriving at the money value of fertilizers. (432) While such a system of valuation may be of some limited value for a short period of time and when applied to a

small district where the systems of farming do not vary widely, no such set of values has general application to the United States. As has been emphasized before (178), the value of any given feed to the stockman depends on the nature and composition of the other feeds he has at hand. If his chief roughage is alfalfa hay, protein-rich concentrates are often worth less to him than those rich in carbohydrates. On the other hand, if the cheapest roughage he can provide is corn or sorghum silage, low in protein, then concentrates rich in protein will be of higher value to him than those carbonaceous in character.

In planning economical rations for any class of animals the stockman should first choose from suitable feeds a combination, containing the proper proportion of concentrates and roughages, which will supply the necessary total amount of nutrients at the minimum expense. If this ration is too low in protein, protein-rich feeds should be substituted for those lower in protein, until the protein supply is brought to the desired amount. On the other hand, if the ration which supplies the necessary total amount of nutrients is too rich in protein, then carbonaceous feeds should be substituted until the nutritive ratio is widened as much as is desired.

In determining which feeds furnish total nutrients at the lowest price, the comparisons may be made on the basis of the cost per therm of net energy, per feed-unit, or per pound of total digestible nutrients. For the reasons pointed out in preceding articles (177-8), the authors believe that the most convenient system for American farmers is on the basis of the cost per pound of total digestible nutrients. In comparing roughages with concentrates this system gives roughages somewhat too high a relative value, for 1 lb. of total digestible nutrients in a roughage is lower in net energy than 1 lb. of digestible nutrients in concentrates. However, in most cases, the desire will be, not to compare roughages with concentrates, but, instead, to determine which one of several concentrates is the cheapest source of total nutrients, or which of the different available roughages is the most economical feed. To determine which feeds are the cheapest supplements to balance a ration low in protein, it will be found convenient to compute the cost of the different feeds per pound of digestible crude protein.

In comparing the relative cheapness of different feeds, it is reasonable to value marketable farm-grown grain or roughage at the market price less the cost of hauling to market. Feeds which are not usually marketable may be assigned a value based on the cost of production. To the price of any purchased feeds should be added any cost of hauling to the farm. Often, however, purchased concentrates may be brought back to the farm on a return trip from market with little or no additional expense.

193. A comparison of corn-belt feeds for milk production.—To illustrate the manner in which the prices of the available feeds should be studied in computing rations, let us assume that a dairyman in the corn belt

has plenty of the following farm-grown grains: Shelled corn, worth 56 cents a bushel on the farm; oats, worth 35 cents a bushel; and barley, worth 45 cents a bushel. He wishes to feed to his herd the grain which is cheapest, considering its feeding value, and sell that which is highest priced. It will cost $2 a ton to grind these grains, as should always be done for dairy cows. (**656**) This will bring the farm price of ground corn to $22 a ton; ground oats, $23.88 a ton; and ground barley, $24.92 a ton. This farmer has his farm laid out in well-planned crop rotations and consequently has plenty of red clover hay and corn silage for his herd, and also some timothy hay. On the farm unbaled clover hay is worth $14 a ton and timothy hay $15 a ton. The cost of raising the corn silage has been not over $4.50 a ton, so this value is taken, since silage has no recognized market value, due to the fact that it is not commonly bought and sold.

The following feeds can be purchased on the local market: Hominy feed at $25 a ton, corn and oat feed at $24, wheat bran at $25, gluten feed at $30, choice cottonseed meal at $35, old-process linseed meal at $35, dried beet pulp at $27, and alfalfa meal at $25 a ton. Limited amounts of these feeds can be hauled home on return trips from town without any material additional expense.

To find which of these feeds are actually the most economical for this dairyman under his own conditions, let us arrange in tabular form the data from Appendix Table III for the different feeds, and compute the cost per pound of digestible crude protein and the cost of 1 lb. of total digestible nutrients in each.

Comparison of the economy of various feeds at the prices stated

Feeding stuff	Dry matter in 100 lbs.	Dig. crude protein in 100 lbs.	Total dig. nutrients in 100 lbs.	Nutritive ratio	Price per ton	Cost per lb. dig. crude protein	Cost per lb. total dig. nutrients
	Lbs.	Lbs.	Lbs.	1:	Dollars	Cents	Cents
Farm-grown grains							
Dent corn, ground	89.5	7.5	85.7	10.4	22.00	14.67	1.28
Oats, ground	90.8	9.7	70.4	6.3	23.88	12.31	1.70
Barley, ground	90.7	9.0	79.4	7.8	24.92	13.84	1.57
Purchased concentrates							
Hominy feed	89.9	7.0	84.6	11.1	25.00	17.86	1.48
Corn and oat feed	88.6	7.3	75.6	9.4	24.00	16.44	1.59
Wheat bran	89.9	12.5	60.9	3.9	25.00	10.00	2.05
Gluten feed	91.3	21.6	80.7	2.7	30.00	6.94	1.86
Cottonseed meal, choice	92.5	37.0	78.2	1.1	35.00	4.73	2.24
Linseed meal, old process	90.9	30.2	77.9	1.6	35.00	5.79	2.25
Dried beet pulp	91.8	4.6	71.6	14.6	27.00	9.35	1.89
Roughages							
Timothy hay	88.4	3.0	48.5	15.2	15.00	25.00	1.55
Red clover hay	87.1	7.6	50.9	5.7	14.00	9.21	1.38
Corn silage	26.3	1.1	17.7	15.1	4.50	20.45	1.27
Alfalfa meal	91.2	10.2	50.7	4.0	25.00	12.25	2.47

This table does not assume to represent average conditions in any district of the country, but illustrates the manner in which any stockman may compare the relative economy of the different available feeds at local prices. The last column shows clearly that under these particular conditions ground corn is by far the cheapest source of total digestible nutrients among the concentrates. Moreover, at the prices stated it furnishes total digestible nutrients at less cost than any of the roughages except corn silage. Next to ground corn and corn silage in economy in supplying total digestible nutrients, comes red clover hay. This furnishes each pound of total digestible nutrients at 1.38 cents, while the cost in timothy hay is 1.55 cents. In addition, clover is much richer in protein than is timothy and is much more satisfactory from other standpoints for feeding dairy cows. (**347, 609, 614**)

With feeds at the prices indicated, it will be noted that the protein-rich concentrates are all more expensive as sources of total digestible nutrients than corn, oats, barley, hominy feed, or corn and oat feed. Therefore for economy in feeding, only sufficient of these supplements should be fed to balance the ration properly.

For balancing a ration deficient in protein, choice cottonseed meal will furnish digestible crude protein at decidedly the lowest cost, 4.73 cents per pound. Next comes linseed meal, supplying digestible crude protein at 5.79 cents a pound, and then gluten feed, furnishing it at 6.94 cents a pound. In supplying protein these feeds will of course also furnish carbohydrates and fat as well, which are included in the total digestible nutrients along with the protein.

Wheat bran supplies protein less economically than cottonseed meal, linseed meal, or gluten feed at the prices stated, but furnishes total digestible nutrients at slightly less cost than the cottonseed or linseed meal. Dried beet pulp is an uneconomical feed at $27 per ton, if considered merely from the standpoint of the nutrients it furnishes. However, it may be desirable to use wheat bran or perhaps dried beet pulp in the ration on account of their palatability and bulkiness, especially for high producing cows. At these prices alfalfa meal is considerably less economical than wheat bran.

194. A corn-belt ration for milk production.—From the feeds listed let us now formulate the most economical ration which will be satisfactory for a 1,200-lb. cow yielding daily 30 lbs. of 3.5 per ct. milk. For this cow there is required, according to the Morrison, or modified Wolff-Lehmann standards (Appendix Table V), a daily allowance of 2.31 to 2.67 lbs. digestible crude protein and 18.03 to 18.99 lbs. total digestible nutrients. As is pointed out in other chapters, feeding the larger amounts of digestible crude protein and total digestible nutrients will result in greater production, but may not sometimes be most profitable. The ration should contain from 25 to 30 lbs. of dry matter, and should have a nutritive ration no wider than 1 : 6.1 to 1 : 7.2. (**186, 572-3**)

Altho corn silage is slightly the cheapest roughage, some dry roughage should be fed with it to dairy cows. (**629, 648**) Of the dry roughages, clover hay is the cheapest. Let us then follow the general rule of feeding 1 lb. of dry roughage and 3 lbs. of silage per 100 lbs. live weight. (**167**) To this allowance of roughage, we will add enough corn to bring the total digestible nutrients up to the amount advised in the standard, for corn is the concentrate which furnishes total digestible nutrients most cheaply. Tabulating the results, we will have:

First trial ration for 1,200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs	10.45	0.912	6.108	8.40	
Corn silage, 36.0 lbs	9.47	0.396	6.372	8.10	
Corn, dent, 8.0 lbs	7.16	0.600	6.856	8.10	
Total	27.08	1.908	19.336	24.60	1:9.1

This ration, which cost 24.60 cents, meets the standard in total digestible nutrients and dry matter but is decidedly deficient in protein. We could narrow the nutritive ratio by feeding less silage and more clover hay, but corn silage is the cheapest feed available. Therefore we should substitute protein-rich concentrates for a part of the dent corn.

If 1.5 lbs. of cottonseed meal was substituted for the same weight of corn, the ration would furnish about 2.3 lbs. of digestible crude protein, the minimum amount recommended in the standard. Ground corn and cottonseed meal are, however, both heavy feeds, weighing about 1.5 lbs. per quart. (Appendix Table IX.) It is hence desirable to add some bulky concentrate which is also high in protein. Wheat bran is a bulky, protein-rich feed and at these prices is fairly economical. Moreover, it is palatable and has a beneficial laxative effect. Thus it is an excellent concentrate to feed with cottonseed meal, which is slightly constipating in its action. Let us then substitute 1.25 lbs. cottonseed meal and 1.5 lbs. wheat bran for the same weight of corn, and again tabulate the results:

Second trial ration for 1,200-lb. cow yielding 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs	10.45	0.912	6.108	8.40	
Corn silage, 36.0 lbs	9.47	0.396	6.372	8.10	
Corn, dent, 5.25 lbs	4.70	0.394	4.499	5.78	
Cottonseed meal, 1.25 lbs	1.16	0.462	0.978	2.19	
Wheat bran, 1.5 lbs	1.35	0.188	0.914	1.88	
Total	27.13	2.352	18.871	26.35	1:7.0

This ration, which costs 26.35 cents, supplies more than the minimum amount of protein recommended by the standard, and is close enough to

it in total digestible nutrients. Tho costing 1.75 cts. more than the first ration, it will be more economical, for it should produce much better results. The concentrate mixture weighs about 1.0 lb. per quart, being about the weight advised by many expert dairymen.

It is explained elsewhere that the lower amounts of digestible crude protein advised for the dairy cow in the Morrison feeding standards are the amounts recommended in the Haecker standards, while the higher figures are those advised by Savage. (**182, 184, 186; Appendix Table V**) As has been stated before (**186**), for cows of pronounced dairy temperament it may be advisable to feed as much protein as called for by the higher figures, providing this does not greatly increase the cost of the ration. Let us then see how cheaply a ration can be provided which will supply 2.67 lbs. of digestible crude protein, the higher figure advised by the standard. The protein can be added most cheaply by substituting more cottonseed meal for corn. We find that by increasing the cottonseed meal 1.0 lb. and decreasing the corn the same amount, we will about meet this figure, as shown in the following table:

Third trial ration for 1,200-lb. cow producing 30 lbs. of 3.5 per ct. milk

Feeding stuff	Dry matter	Dig. crude protein	Total dig. nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12 lbs	10.45	0.912	6.108	8.40	
Corn silage, 36 lbs	9.47	0.396	6.372	8.10	
Corn, 4.25 lbs	3.80	0.319	3.642	4.68	
Cottonseed meal, 2.25 lbs	2.08	0.832	1.760	3.94	
Wheat bran, 1.5 lbs	1.35	0.188	0.914	1.88	
Total	27.15	2.647	18.796	27.00	1:6.1

This ration, which has a nutritive ratio of 1:6.1, costs 0.65 cent more than the preceding ration. Whether this ration, higher in protein, will produce enough more milk to pay for the increased cost will depend on how pronounced is the dairy temperament of the particular cow getting the ration. This concentrate mixture contains a fair variety of feeds, has plenty of bulk, and would give excellent results. Some dairymen might prefer to substitute 1 lb. of linseed meal for 1 lb. of cottonseed meal, thus providing still greater variety. At the prices stated, this change would not increase the cost, but would lower the protein a trifle.

Reducing the amount of corn 0.75 lb. would bring the total digestible nutrients to 18.152 lbs., about the lower figure recommended in the standard, saving 0.82 cent. Except for cows of superior productive capacity, this might be economical if concentrates were very expensive compared with roughage. At the prices taken in this example, however, corn furnishes total digestible nutrients cheaper than any other feed except corn silage, and nearly rivals the latter in economy. Under such conditions it will pay to be fairly liberal in the amount of grain fed. (**198, 646**)

After an economical ration has been computed in this manner for the average cow in the herd, it is not necessary to work out a ration similarly for the other cows in the herd which differ in live weight and milk production from this average cow. All that is needed is to modify this ration according to the thumb rules given elsewhere in this volume. (**167, 647**)

195. Purchasing concentrates on the basis of net cost.—On most farms in the United States the maintenance of soil fertility is an important problem, and one always to be considered in the purchase of feeds. It is pointed out in Chapter XVII that in determining which concentrates are really the most economical to buy, the manurial value of the feed per ton should be deducted from the actual cost. This manurial value is the fertilizing value actually returned to the soil by applying the manure produced thru feeding a ton of the feed. (**437**) It is there shown that quite commonly in the corn belt and many other sections of the country when credit is given for their high manurial value, the net cost per ton of such protein-rich concentrates as cottonseed meal is actually lower than the net cost of carbonaceous concentrates, including the farm-grown grains. Under such conditions, even without taking into account their high feeding value as supplements to farm-raised feeds, but merely crediting them with their manurial values, they are really the cheapest concentrates which can be used. They are far from being "high-priced purchased feeds," as they are often termed by those who do not realize their dual value as both protein-rich supplements and later as fertilizers.

196. A cotton-belt ration for milk production.—Let us next use the method which has just been illustrated to determine the most economical ration for the same cow if owned by a southern dairyman who has plenty of cowpea hay, worth $15 a ton, and corn silage, worth $5 a ton, for roughage. Ground corn is worth $38 per ton, and ground oats, $42 per ton. He can purchase choice cottonseed meal at $33 per ton, wheat bran at $35, velvet bean feed (crushed velvet beans and pods combined) at $33, and cottonseed hulls at $14 a ton.

At these prices, it will be found that cottonseed meal furnishes total digestible nutrients at 2.11 cents per pound, which is less than in the case of any of the other concentrates available. Velvet bean feed comes next, supplying total digestible nutrients at 2.19 cents per pound. The cost in corn is 2.22 cents, in oats 2.98 cents, and in wheat bran 2.87 cents. Thus, under these conditions, cottonseed meal and velvet bean feed, which are both rich in protein, furnish total digestible nutrients more cheaply than the carbonaceous feeds—corn and oats.

The larger the proportion of cottonseed meal or velvet bean feed which is used in the concentrate mixture for the cows, the cheaper will be the ration. The conditions are therefore just opposite to the case of the corn-belt dairyman, for with feeds at his prices, a ration high in protein was more expensive, tho more efficient, than an unbalanced one low in protein. Under such conditions as those of this southern dairyman, it

is needless to compute the cost of the different feeds per pound of digestible crude protein. All we need to consider is the economy with which they supply total digestible nutrients and also the facts concerning the general characteristics of each feed.

The cheapest ration for this cotton-belt dairyman to feed would be only cottonseed meal as the concentrate, with cowpea hay and corn silage for roughage. However, it is not safe to feed over 4 pounds of cottonseed meal per head daily to dairy cows over long periods. (**596**) Therefore, some other feeds lower in protein must be used to replace part of the cottonseed meal. Ground corn is but slightly more expensive per pound of total digestible nutrients than the cottonseed meal, and should therefore be the chief concentrate used along with it. Wheat bran is a bulky feed and is well suited for feeding with cottonseed meal, It is therefore advisable to include a small amount in the concentrate mixture.

Taking all the facts into consideration, it will be found on computing rations as in the preceding paragraphs that an economical and efficient ration would be cottonseed meal, 4 pounds; ground corn, 2.5 pounds; and wheat bran, 1.5 pounds; fed with 12 pounds of cowpea hay and 36 pounds of corn silage. Velvet bean feed could be substituted for part of the cottonseed meal without increasing the cost materially.

II. Adapting Systems of Feeding to Local Conditions

197. Amount of protein to supply.—The illustrations given in the preceding articles show clearly that rations should be adapted to the local conditions. Feeding standards set forth approximately the amount of protein and total nutrients, which it is believed should be furnished for the maximum production of flesh, milk, work, etc., and for maintaining the highest well-being of the animal. It will be noted that in the Morrison standards a range is indicated in the amount of digestible crude protein which is advised for most classes of farm animals. For example, for 2-year-old steers on full feed from 1.9 to 2.2 lbs. of digestible crude protein per 1,000 lbs. live weight are recommended for the first 50–60 days of fattening. When protein-rich feeds cost but little or no more than carbonaceous feeds, it is well to feed at least as much protein as indicated by the higher figures. On the other hand, when corn or the other grains are relatively cheap, it may be better economy to feed no more protein than called for by the lower figures. Rarely is it advisable to feed a materially smaller allowance of protein than the lower figures, for the production will be thereby lowered.

As is shown later (**732, 843-4**), corn and clover hay alone make a fairly well-balanced ration for fattening cattle and sheep. However, the gains are usually slightly increased and a higher finish secured when a small allowance of some suitable nitrogenous concentrate is added to the ration. Whether such addition will be profitable or not depends on the prices

of the feeds and on whether the market will pay a better price for the more highly finished animal. (733, 858)

When protein-rich feeds supply nutrients more cheaply than those carbonaceous in character, as in the cotton belt and the alfalfa districts of the West, it will be economy to feed much more than the minimum amounts of protein set forth in the standards. (612, 768) However, protein should not be supplied in such excess as to injure the health of the animals.

198. Proportion of concentrates to roughages.—To meet the standards for fattening cattle and sheep and for milk cows, fairly liberal amounts of concentrates are required. At prices current before the World War, concentrates often furnished total digestible nutrients nearly as cheaply as did roughages. Under such conditions it is advisable to feed as large a proportion of concentrates as is called for by the standards. (716, 902, 906-7)

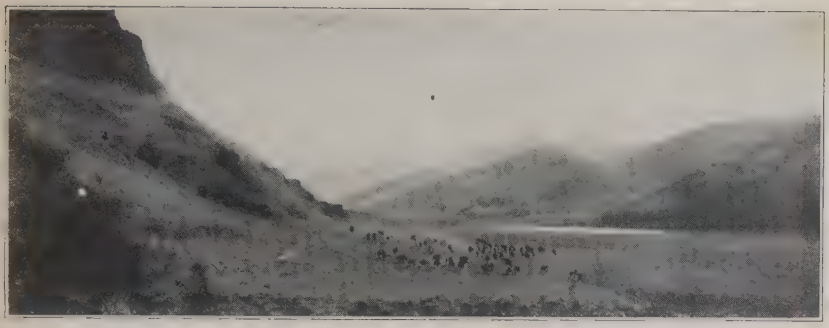
On the other hand, during and immediately after the war roughages were usually decidedly more economical than concentrates in most parts of the United States, and hence it was profitable to feed less concentrates than under pre-war conditions. For example, it is shown later that in some of the feeding trials carried on during that time steers fed no corn except that in corn silage returned more profit than others fed the usual allowance of corn. (715)

Now grain and some other concentrates are back to pre-war levels or even lower in the corn belt and some other sections, while roughages have fallen less in price. In these districts, concentrates again furnish nutrients nearly as cheaply as roughages, and in some instances even more economically. Therefore the conditions under which liberal feeding of concentrates is advisable have again returned.

With dairy cows much depends on the productive capacity of the animal. Except when concentrates are unusually high in price, the cow of good dairy temperament will pay for at least a fair allowance of concentrates. On the contrary, for a low or limited productive capacity the most economical ration, when concentrates are relatively high in price, may be silage and legume hay with no concentrates. (612)

The recommendations in the feeding standards for growing cattle and sheep are based upon continuous thrifty growth, and hence call for a limited allowance of concentrates in addition to roughage. The breeder of pure-bred animals who wishes to develop the best there is in his young stock will feed the concentrates needed to keep them growing rapidly. On the other hand, the western beef producer may find it most profitable to carry young stock thru the winter on roughage alone or with but a small allowance of concentrates. Thus fed, they will gain in frame, and tho losing in flesh, will be thrifty enough in the spring to make good gains on the cheap pasturage. (137-8, 797-9)

199. Finish animals to meet demands of the market.—The wise stockman will keep in close touch with the demands of the market and adjust



BEEF CATTLE ON THE WESTERN RANGE

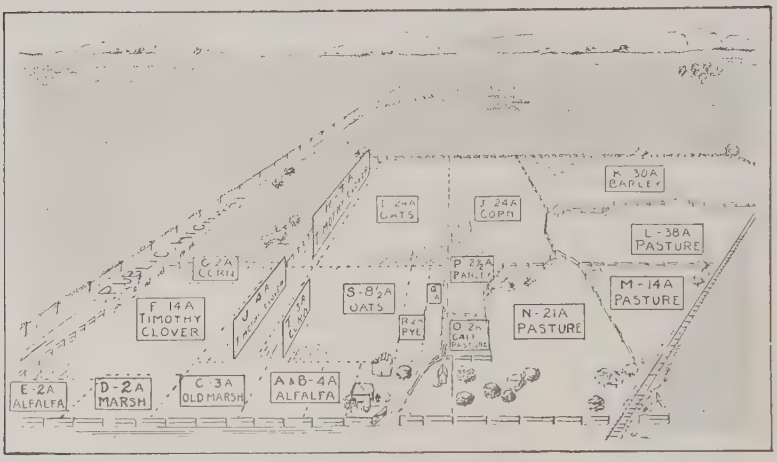
In the range districts of the West pasturage is cheap, but concentrates are high in price. Hence beef cattle are raised on the range and sold as feeders to be fattened in grain raising districts. (From *Breeder's Gazette.*)

A BEEF FARM IN NORTHEASTERN KANSAS

The bottom lands are in corn and the sloping hillsides in hay, while the broken limestone hills in the background are pastured. Here beef calves are raised and also fattened for market. (From U. S. Department of Agriculture.)

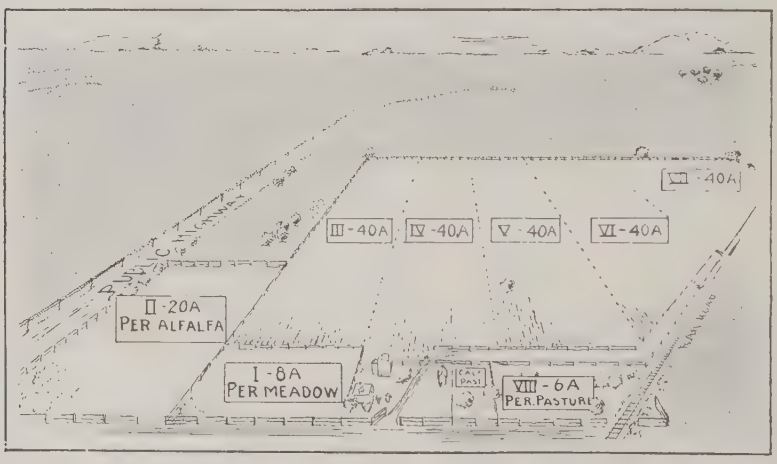
FATTENING BEEF CATTLE ON GRASS IN THE CORN BELT

On high-priced land, with few acres unsuited for tillage, the stockman has generally found it more profitable to fatten feeder cattle brought from the ranges than to raise his own feeders.



A Poorly Planned Farm

This dairy farm was poorly arranged for economical cultivation, for it was cut up into many fields, irregular in size and shape. There was no well-planned rotation system, and but little legume hay was grown. (From Wisconsin Station.)



The Same Farm Efficiently Laid Out

This shows the same farm as laid out by an expert in farm management. Fields III to VII are in the following definite 5-year rotation: First year, grain seeded to alfalfa; second year, alfalfa; third year, alfalfa; fourth year, alfalfa; fifth year, corn. This rotation provides a well-balanced ration for the milk cows without much purchased feed, for there is plenty of legume hay. Note that the fields are of equal size and that they are large and so shaped that time is saved in tilling them. Fields I and II are permanently in hay and Field VIII is in permanent pasture. (From Wisconsin Station.)

his feeding operations accordingly. If the market pays a sufficient premium for thoroly fattened animals he will finish his stock well before marketing them. On the other hand, on local markets which pay no more for a prime carcass than for one carrying less fat, it will not pay to prolong the fattening process or to feed as heavy an allowance of concentrates as is necessary to make the carcass "ripe," or thoroly fat. (122-3, 715-6, 768, 902)

200. Adapt type of farming to local conditions.—It is outside the field of this volume to discuss in detail the many factors which the stockman should take into consideration in deciding the type of live-stock husbandry in which to engage and the systems and methods to follow. The foregoing paragraphs serve to illustrate how the farm operations and practices should be suited to local conditions, taking into consideration prices of land and labor, nearness to market, and available crops. For example, the beef producer on high-priced land in the eastern part of the corn belt will generally crowd his calves to rapid growth on a heavy allowance of grain and fatten them as baby beef. Or he will raise no cattle, but fatten feeder steers from the western ranges on a liberal allowance of corn. On the other hand, in the West where pasture is cheap compared with grain the stockman will usually follow a less intensive system, roughing his growing stock thru the winter and marketing them from grass as 2- or 3-yr.-olds, having been fed little grain at any time.

The market milk for our cities must come from the surrounding districts which are within easy shipping distance. Dairymen maintaining herds on high-priced land to meet this demand properly tend to use a minimum acreage as pasture, but instead rely largely on corn silage or soilage during the summer months. They often buy much of their concentrates, for grain can be produced on land farther from market and shipped in at less expense than it may be possible to grow it on their farms. Such a system is not, however, economical for the dairyman remote from the large markets, whose milk is used in the manufacture of butter or cheese. Since with him land is relatively less expensive than labor, he must adopt a less intensive system of dairying, where the herd is maintained largely on pasture in the summer.

The reader will come to realize as he goes on in this book that, while there are no hard and fast rules for successfully managing live stock, a clear understanding of the principles of the nutrition of animals is essential to the highest success. This must be supplemented by good judgment and by a thoro knowledge of the farm animals themselves, which can only be gained by actual experience. He will further find that expensive buildings for housing stock and complex devices for feeding and caring for them are not necessary; that there are no "best" feeds for all conditions; that elaborate and laborious preparation of feed is often wasted; that patent stock foods guaranteed to work miracles enrich, not the farmer, but the manufacturer.

On the other hand he will come to appreciate that a proper balancing of the rations for his stock not only benefits the animals, but also increases his profits; that comfort for farm stock can be secured in inexpensive, easy ways, and that the operations of preparing and administering feed are really simple and direct, when once understood. He will further come to the deep and fundamental realization that animal husbandry under normal conditions is most successful when combined with general farming and the raising of farm crops, that it rests upon pasture lots which are fertilized so as to produce abundant forage and upon tilled fields which are so managed that the fertility is maintained and bumper crops are grown, a large part of which is marketed thru the animals of the farm.

Having discussed in the preceding chapters the fundamental principles governing the rational feeding and care of the various classes of farm animals, let us now consider in detail the value of the many different feeding stuffs for live stock.

Part II

FEEDING STUFFS

CHAPTER IX

LEADING CEREALS AND THEIR BY-PRODUCTS

I. Indian Corn and its By-products

The prime importance of Indian corn, or maize, *Zea mays,* as a grain crop in the United States is evident from the fact that in 1921, about 103,850,000 acres were grown, producing 3,080,372,000 bushels of grain, worth $1,302,670,000. Before the World War increased the raising of bread grains in this country, our corn crop exceeded in acreage, in production, and in value of grain, that of wheat, oats, barley, rye, kafir, milo, emmer, buckwheat, and rice, all combined. Indian corn can be successfully grown in every state of the Union, tho it flourishes best in the great region between the Appalachians and the Rocky Mountain Plateau. In the South the tropical corn stems, 4 or 5 months from planting, carry great ears burdened with grain so high that a man can only touch them by reaching high above his head. At the other extreme, the Mandan Indian in the country of the Red River of the North developed a race of corn which reached only to the shoulders of the squaw, with tiny ears borne scarcely a foot from the ground on pigmy stalks. Corn is a heat-loving plant, and will not thrive in regions having cool nights during the growing season.

Like the other leading cereals which grow *en masse,* the corn plant must grow with others of its kind, but it requires more space, air, and sunlight. Because it requires thoro tillage and makes most of its growth during late summer and early fall, Indian corn stands in a class by itself among the cereals. (23) This requirement of thoro tillage brings many advantages to the soil not forced upon us in growing the other cereals. The corn grain is pre-eminently a carbohydrate bearer, every 100 lbs. containing nearly 70 lbs. of starch, which is its chief carbohydrate. Add to this 5 lbs. of oil, and we can understand why Indian corn among the cereal grains may be likened to anthracite coal among the fuels.

Corn is the great energizing, heat-giving, fat-furnishing food for the animals of the farm. No other cereal yields, on a given space and with a given expenditure of labor, so much animal food in both grain and forage. On millions of farms successful animal husbandry rests upon this imperial grain and forage plant. (475, 575, 732-7, 843-6, 938-42) A pos-

sible explanation of the great fondness of farm animals for corn lies in the considerable amount of oil it carries. Again, on mastication the kernels break into nutty particles which are more palatable, for example, than meal from the wheat grain, which on crushing and mingling with the saliva turns to a sticky dough in the mouth. (For a discussion of corn as a forage, see Articles **293** to **307**.)

201. Corn lacks protein and mineral matter.—Being so rich in carbohydrates, corn is naturally low in crude protein. The crude protein of this grain is also somewhat unbalanced, for about 58 per ct. of it consists of the single protein, zein, which lacks some of the amino-acids necessary for animal growth. (**118**) Corn is also unusually low in mineral matter, especially calcium, so necessary for growing animals. Numerous experiments show that even with fattening animals, which require relatively little protein and mineral matter, it is profitable to supplement these deficiencies of the corn grain by other feeds high in the nutrients which corn lacks. (**732, 844, 938**) Fortunately, the legume hays are rich in protein and calcium, and therefore admirably supplement corn. By the use of these roughages, less protein-rich concentrates are needed to balance a heavy allowance of corn. Indeed, for some animals legume hay and corn alone form a satisfactory, well-balanced ration. (**733, 844**)

202. Races of corn.— Three races of corn—dent, flint, and sweet—are of interest to the stockman. In dent corn the starch is partly hornlike and partly floury, rendering the kernel easy of mastication. In flint corn the starch is mostly hornlike and flinty, making the kernel more difficult for the animal to crush. The feeding value of dent corn and flint corn is approximately the same.

Until recently chemists were able to discover no difference in the feeding value of white and yellow corn. Steenbock, however, has found at the Wisconsin Station that yellow corn contains much more fat-soluble vitamine than white corn. (**104**) In feeding trials by Morrison and Bohstedt at the same station (**939**), for pigs not on pasture yellow corn has proven better than the white when fed with other feeds low in this vitamine. Since green-leaved roughages probably all contain an abundance of this vitamine, it is doubtful whether there is any difference when good-quality roughage forms a considerable part of the ration, as in the case of dairy cows, beef cattle, horses, and sheep, even on winter rations, and for all animals on good pasture. For instance, yellow corn was no better than white for pigs on pasture.

In sweet corn the starch is hornlike and tough. Before hardening, the milky kernels of this race carry much glucose, which is changed to starch as they mature into the shrunken grain. The sweetness of the immature grains of sweet corn, due to the glucose they then carry, adds to the palatability but not necessarily to their nutritive value, since glucose and starch have the same feeding value. (**48**) Sweet corn has somewhat more protein and fat and less carbohydrates than the other races. Earliness of maturity tends to dwarf the corn plant. Hence, the

higher the latitude or the altitude at which a variety was originated the larger will be the proportion of ears to stalk and leaves, tho the total yield of ears will usually be decreased.

203. Corn cobs.—Well-dried dent ear corn of good breeding carries about 56 lbs. of shelled corn to 14 lbs. of cob. The proportion of cob to grain varies according to race, variety, and dryness, ranging from below 20 to about 40 per ct., flint varieties having a larger proportion of cob to grain than does dent corn. The cobs carry about 30 per ct. of fiber, which at best is of low feeding value, and much of their nitrogen-free extract is in the form of pentosans. (9) Since the cobs have some nutritive value, under certain conditions it is profitable to grind the whole ear into corn-and-cob meal. (208) Manifestly it is not economical to purchase ground corn cobs in adulterated commercial feeds at a price that would buy good concentrates. (288)

204. Water content and shrinkage of corn.—The amount of water in shelled corn a year old will vary from less than 10 per ct. to about 14 per ct., depending on the dryness of the climate. Freshly husked corn may contain 35 per ct. or more of water.[1] Rarely will ear corn containing over 20 per ct. water keep if stored in any considerable quantity. Shelled corn may spoil when stored in bulk if it contains more than about 14 to 15 per ct. moisture.

As ear corn dries out the weight shrinks, due chiefly to the evaporation of water but also due in small part to a decomposition or oxidation of some of the nutrients in the grain. The rate of shrinkage depends not only on the maturity of the corn when husked, but also on the moisture content of the air. When the moisture content falls to 12 per ct., shrinkage practically ceases. A large part of the shrinkage of ear corn is in the cobs, which usually form about one-fourth of the weight of the ears at husking and one-fifth of their cured weight. In studies at the Kansas,[2] Illinois,[3] and Iowa[4] Stations ear corn fairly dry when cribbed shrank from 3.3 to 9.7 per ct. on the average from November to March. The average shrinkage in a year ranged from 8.6 per ct. to 19.4 per ct. Twisting the ears slightly will fairly indicate the moisture contained. Loose grained, "sappy" ears carry too much moisture to be cribbed safely.

Corn is stored mostly on the husked ear in the North, but in the South the husks are left on the ears because of the weevil, a beetle that injures the kernels unless they are protected. As corn keeps better in the ear than when shelled, it should be held in this form as long as possible.

Seventy lbs. of dry dent corn of good varieties will make 1 bushel, or 56 lbs., of shelled corn, but in early fall the buyers frequently demand 75 or 80 lbs., according to the estimated water content. According to the Federal corn grades, by which corn is sold on the large markets, the percentage of water in corn must not exceed for Number 1, 14 per ct.; Number 2, 15.5 per ct.; Number 3, 17.5 per ct.; Number 4, 19.5 per ct.;

[1]Iowa Bul. 77. [2]Kan. Bul. 144. [3]Ill. Bul. 113. [4]Hoard's Dairyman, 49, p. 463.

Number 5, 21.5 per ct.; and Number 6, 23 per ct. Obviously, the value of corn for feeding depends on the amount of water it contains. Therefore, in Appendix Tables I and III the composition of the various grades is shown separately.

205. Soft corn.—Corn frosted before the grains mature contains too much water for storage or shipment, and is best utilized by immediate feeding or placing the entire crop in the silo. Soft corn, when not moldy, may be fed to all classes of stock. Moldy corn is especially dangerous for horses and sheep. Cattle are not commonly injured by moldy corn, and hogs can usually be trusted to eat what they will. Fattening pigs are especially adapted to disposing of soft corn, and good results have also been secured with cattle, especially with stock cattle, or fattening cattle in the first part of the fattening period. As a rule, 100 lbs. of dry matter in soft corn which has not spoiled may be considered equal in feeding value to 100 lbs. of dry matter in mature corn. When soft ear corn must be cribbed, it should be stored in well ventilated cribs. Sprinkling over the corn 1 to 2 lbs. of common salt per 100 lbs. of ear corn aids in preventing mold.[5]

Snapped soft corn (ears and husks) may also be ensiled and then fed in place of ear corn or shelled corn to fattening cattle, sheep, or swine.[5a] The snapped corn must be chopped fine by running it thru a silage cutter and must be tramped well in the silo. If the corn is in the late roasting stage a ton of water should be added to every 6 to 7 tons of ears. If the ears are in the milk it may not be necessary to add water.

206. Composition of the corn kernel.—Appendix Table I shows that air-dry dent corn contains 70.9 per ct. nitrogen-free extract—nearly all starch—and only 2.0 per ct. fiber, which comprises the fiber of the hull, or skin, of the kernel, and of the cell walls inclosing the starch grains. On comparing the composition of corn with that of the other common cereals, it will be noted that corn is by far the richest in fat, containing 5.0 per ct. fat, or oil. Because of this abundance of starch and oil, corn excels as a fattening food. Corn has slightly less crude protein than wheat, barley, oats, or rye and is also lower in ash. It is especially deficient in lime, containing only 0.2 lb. per 1,000 lbs. of grain. As has been emphasized before (**201**), in feeding corn we must bear in mind these facts concerning its composition. Fed without any protein-rich supplement, corn makes a decidedly uneconomical ration.

Studying the composition of the different parts of the kernel of dent corn, Hopkins of the Illinois Station[5b] found that in 100 lbs. of water-free corn the hulls and tip caps together weighed 7.4 lbs.; the horn-like layer of gluten just under the skin, 8.5 lbs.; the flinty, horn-like starch at the sides and back of the kernel, 47.1 lbs.; the floury starch at the tip of the kernel and partially surrounding the germ, 25.5 lbs.; and the germ, 11.5 lbs. The floury starch contains over 90 per ct. starch, only 7.8 per ct. crude protein and less than 1 per ct. fiber, with but a trace of

[5]Hughes, Iowa Cir. 41. [5a]Evvard, Iowa Cir. 40. [5b]Ill. Bul. 87.

fat and ash. The flinty starch also consists mostly of starch, but carries more protein than the floury starch. The hulls and tip caps are likewise composed largely of carbohydrates, tho containing less starch and about 15 per ct. fiber. The horn-like gluten is rich in crude protein (containing about 22 per ct.), and the germ carries nearly as much protein and about 35 per ct. oil or fat.

207. Corn meal; corn chop; corn feed-meal.—The term *corn meal,* as applied to feeding stuffs, is most correctly used to denote the entire ground corn grain, from which the bran or hulls have not been removed by bolting. In preparing corn for human food the grain is either ground to a coarse meal or cracked coarsely, the siftings, the hulls, and usually the germs being removed. The milled product, which is likewise called corn meal, has a more attractive appearance than the entire ground grain, but contains somewhat less protein and fat. Much of the commercial corn meal, particularly in the Mississippi valley, is made from the part of the kernel left after the manufacture of cracked corn or table meal. It is most correctly called *corn feed-meal,* and according to Smith and Beals of the Massachusetts Station,[6] is equal in feeding value to corn meal made from the entire grain.

Corn chop is a name sometimes applied to ground corn, and also to mixtures of ground corn and corn by-products. Since it has often been found best not to grind corn for stock (**423, 475, 735, 846, 921**), the question whether this grain should be reduced to a coarse or a fine meal has lost much of the interest once taken in it. On grinding corn the oil it carries soon becomes rancid and gives the meal a stale taste. Hence this grain should never be ground far in advance of use.

208. Corn-and-cob meal.—When ear corn is ground the product is called corn-and-cob meal. Because of the rubber-like texture of the cobs, much power is required to reduce ear corn to meal. Unless the cobs are ground fine so that the particles are small, the animals will not usually eat them. It may be advisable to use corn-and-cob meal in place of corn meal for dairy cows when other bulky concentrates are not included in the ration. (**576**) Corn-and-cob meal is not commonly used for horses, fattening cattle or sheep. (**475, 735-6, 846**) As the digestive tract of the pig is not suited to utilize such fibrous feeds as corn cobs, corn-and-cob meal is inferior to corn meal for swine. (**941**)

209. Starch and glucose by-products.—In the manufacture of commercial starch and glucose from corn, the grain is first passed thru cleaning machinery. It is then soaked in warm water, slightly acidulated with sulfurous acid, which softens the grain and facilitates the separation of the germ. Next the grain is coarsely ground and the mass passed into tanks containing "starch liquor." Here the germs, which are lighter, on account of the large amount of oil they carry, rise to the surface, and are removed. After washing, the residue is then finely ground, and the coarser part, the bran, separated by silk sieves. The remainder,

[6]Mass. Bul. 146.

called "starch liquor," which contains the starch, gluten, and fine particles of fiber, is then passed slowly thru shallow, slightly inclined troughs where the starch settles like wet lime, while the lighter ingredients—the gluten, fiber, etc.—are carried off in the current of water. In this process there are thus obtained, (1) the germ, from which corn oil and germ oil meal or corn oil cake are secured, (2) the bran, consisting of the hulls, (3) the starch, and (4) the gluten. The bran, together with some light weight and broken germs, was formerly dried and sold as *corn bran.* Also the *gluten* was dried, ground, and sold as *gluten meal.* Now, however, the bran and gluten are usually united while still wet, and then dried and ground, the product being sold as *corn gluten feed,* or *corn starch by-product with corn bran,* as it is sometimes called.[7]

210. Corn gluten feed.—Formerly, the steep water, which contains the soluble materials, such as soluble protein and phosphates, was allowed to run to waste. It is now often evaporated and the residue, called corn solubles, is added to the gluten feed. Gluten feed is rich in crude protein, contains a fair amount of carbohydrates and fat, and is bulkier than corn. The protein content varies from 18 to over 29 per ct., depending chiefly on how completely the starch has been removed. The average protein content of high-grade gluten feed is 25.4 per ct. The ash content ranges from less than 1 per ct. when the corn solubles have not been added to 5 or 6 per ct. when this residue has been incorporated. Owing chiefly to the acid nature of some of the protein and phosphorus compounds naturally occurring in the corn solubles, gluten feed to which these have been added has an acid taste unless the acid has been neutralized in the process of manufacture. While the small amount of acid present is probably not injurious to live stock, the feed is more palatable when the acidity is neutralized, as is now usually done.

Gluten feed is extensively used for dairy cows. (**590**) It contains 21.6 per ct. digestible crude protein, while wheat bran contains only 12.5 per ct., and it also furnishes more total digestible nutrients than bran. It is therefore worth considerably more per ton than this feed. Gluten feed may also be satisfactorily fed to beef cattle and sheep as a supplement to rations low in protein. (**757, 856**) As the protein in gluten feed is, of course, corn protein (**201**), gluten feed is not a satisfactory supplement to corn or the other cereals for swine when fed as the only supplement. Better results are secured when gluten feed is fed along with tankage or dairy by-products. (**980**)

211. Gluten meal.—This by-product, now sometimes called *corn by-product without corn bran,* is one of the richest of concentrates in crude protein and fat, while fair in carbohydrates and low in mineral matter. It is a heavy feed, and, as mentioned before, is usually mixed with corn bran to form gluten feed. (**491, 591, 980**) As gluten meal is richer than gluten feed in digestible crude protein, it is worth more per ton.

[7]Wagner, U. S. Dept. Agr., Bur. Chem., Bul. 122, 1909, Lindsey, Mass. (Hatch) Bul. 78.

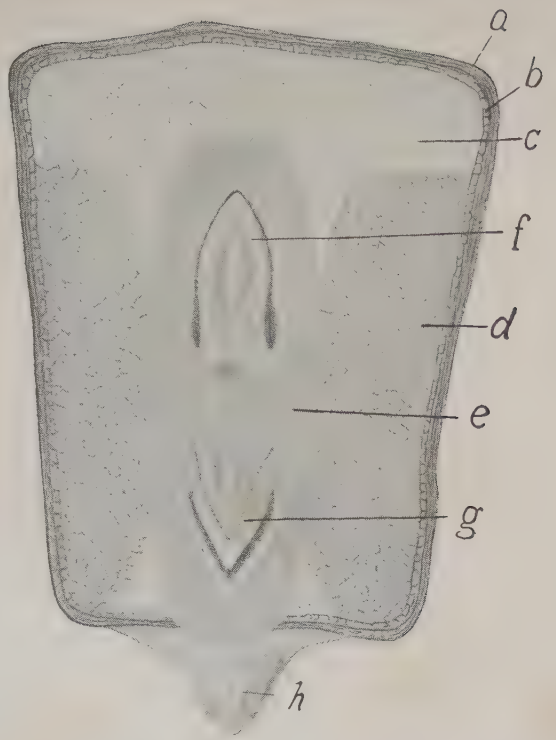


DIAGRAM OF A KERNEL OF DENT CORN

A, hull; b, hornlike gluten; c, floury starch; d, horny starch; e, embryo, or germ; f, embryo stem; g, embryo root; h, tip cap.

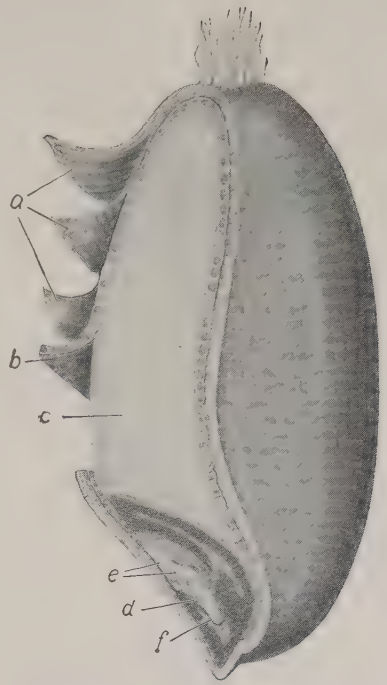
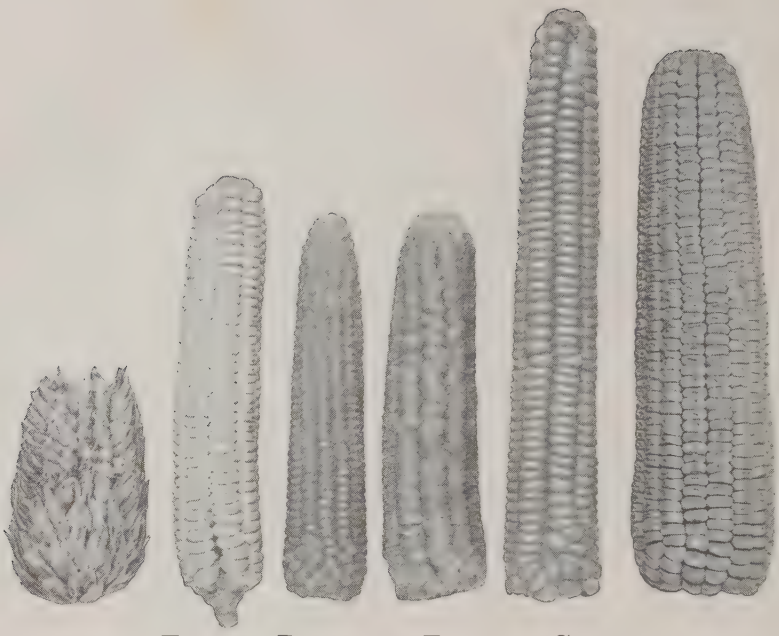


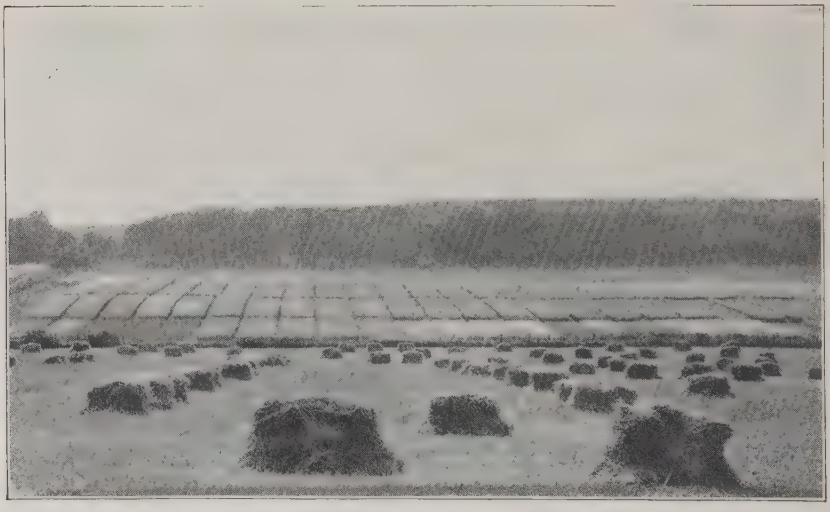
DIAGRAM OF WHEAT KERNEL

A, three bran coats; b, aleurone layer; c, cells filled with starch grains; d, embryo, or germ; e, embryo leaves; f, embryo root. (Partially after Neumann.)



EARS OF DIFFERENT TYPES OF CORN

From left to right: Pod corn, a primitive type; soft corn, an unimproved type having no horny starch; pop corn; sweet corn; flint corn; dent corn. (From Wisconsin Station.)



PROFITABLE CROPS CAN BE EXPECTED ONLY FROM WELL-BRED SEED

By skillful and patient work plant breeders have developed high yielding pedigree varieties of grains particularly adapted to various sections. The view shows the grain-breeding plots at the Wisconsin Station.

212. Corn germ meal.—The corn germs removed in the manufacture of starch are dried, crushed, and much of the oil pressed out, leaving the residue in cakes. This is exported as *corn oil cake,* or ground and sold in this country as *corn germ meal* or *germ oil meal.* This feed contains somewhat less protein than gluten feed, but much more fat. Corn germ meal is chiefly fed to dairy cattle and swine. (**592, 980**)

213. Hominy feed, meal, or chop.—This by-product, variously called hominy feed, hominy meal, or hominy chop, is a mixture of the bran coating, the germ (with or without a partial extraction of the oil), and a part of the starchy portion of the corn kernel. It is obtained in the manufacture of hominy, of hominy grits, and of table corn meal by the degerminating process, where the germs are removed from the table meal. It is a carbonaceous feed, similar in composition to corn, but somewhat more bulky. It is slightly lower in nitrogen-free extract, higher in fiber, and contains more fat. While slightly less digestible than corn meal, it is kiln-dried, almost invariably sweet, and keeps better in storage than does corn meal. As it is a bulkier feed than corn meal, it is preferred by many for dairy cows. (**577**) It is also an excellent feed for swine and may be used as a substitute for corn for cattle or sheep. (**749, 847, 943**)

More or less of the germs are now removed from some brands of hominy feed. This, of course, decreases the feeding value, as such hominy feed is lower in protein.

214. Corn bran.—But little corn bran now comes upon the market as such, for, as we have seen, it is usually mixed with other by-products. (**209**) Corn bran contains about three-fifths as much protein as wheat bran, is somewhat higher than that feed in nitrogen-free extract and fat, and contains slightly more fiber.

II. Wheat and its By-products in Milling

Since it costs more to produce wheat, *Triticum sativum, tenax,* than corn, and since our population is steadily increasing, it is reasonable to suppose that wheat will never again be used in any considerable amount for feeding stock in this country, as it was at one time. But the feeder should know both its absolute and relative value, for the low grades of wheat had better be fed to stock than sold.

215. Wheat as a feed.—Compared with corn, wheat carries slightly more carbohydrates in the form of starch, more crude protein, and much less fat. Tho low in mineral matter, it contains somewhat more lime, phosphoric acid, and potash than corn. While the nutritive ratio of dent corn is 1:10.4, that of wheat is 1:7.7. Tho wheat thus carries a larger proportion of protein, this nutrient is unbalanced in composition, like that of corn.[8] (**118**)

That the wheat grain seems to contain some substance which is injurious when fed in too large amounts has been pointed out before. (**166**)

[8]Hart et al., Jour. Biol. Chem., 19, 1914, pp. 373-395.

In ordinary well-balanced rations containing a variety of proteins there is commonly no difficulty from this source.[9] Like corn, wheat should be supplemented by feeds which are rich in protein and lime. Fed in properly balanced rations wheat is about equal to corn for milk production or for fattening animals. (**578, 739, 849, 945**) When fed in large amounts to horses it has occasioned digestive disturbances and eruptions of the skin. (**479**) Because the kernels are small and hard, wheat should be ground for all farm animals except sheep. Ground wheat or wheat flour, fed alone, often forms a pasty mass in the animal's mouth. To avoid this bran or coarse corn meal can be added, or the wheat or flour may be fed as a slop. (**945**)

As stated before (**81**) the composition of the wheat kernel is markedly influenced by climate, especially in protein content. Wheat from the northern plains region is highest in crude protein, while that from the Pacific coast districts is unusually low in this nutrient. When grown under the same climatic conditions spring wheat is usually slightly richer in crude protein than winter wheat.[10] Durum or macaroni wheat is extensively grown in parts of the plains states, especially the Dakotas, on account of its higher yield in these sections. This variety shows no appreciable difference in composition or feeding value from ordinary wheat grown under the same environment.[11] (**849**)

Wheat growers should sell only the best grades, retaining for their animals all shrunken, frosted, or otherwise damaged grain, for while such wheat has low selling value, it is often equal to grain of good quality for feeding. (**739, 849, 945**) As a rule such grain is richer in protein than is wheat of good quality.

Salvage grain, which has been slightly charred or injured by smoke and water in elevator fires, thus being unfitted for human food, may have its value for stock feeding but little impaired.

216. Flour manufacture.—The wheat kernel is covered with three straw-like coats or skins. Beneath these comes the fourth, called the "aleurone layer," rich in crude protein, and which in milling goes with the other coats to form bran. The germ, or embryo plant, in each kernel is rich in oil, crude protein, and mineral matter. The remainder of the kernel consists of thin-walled cells packed with starch grains. Among the starch grains are protein particles called "gluten," that give wheat-flour dough the tenacity so essential in bread making. In producing flour the miller aims to secure all the starch and gluten possible from the wheat grains, while avoiding the germ and bran. He leaves out the germs because they make a sticky dough and also soon turn dark and rancid, giving the flour a specked appearance. Nor does he use the aleurone layer, as it gives a brownish tint to the flour.

In modern milling, flour is produced by passing the thoroly cleaned wheat thru a series of steel rollers, each succeeding pair being set a little nearer together so that the kernels are gradually crushed into

[9]Wis. Bul. 287. [10]Bailey, Minn. Bul. 143. [11]Ladd and Bailey, N. D. Bul. 93.

smaller and smaller particles. After passing thru each pair of rollers, or "breaks," the flour is removed by sifting or passing the material over bolting cloth, and finally only the by-products remain.

The terms employed to designate the various mill products differ somewhat in various sections of the country, but those most commonly used are *wheat bran, standard middlings* or *shorts, white* or *flour middlings, red dog flour* and *wheat mixed feed.*

In the manufacture of flour, from 20 to 30 per ct. of the weight of the wheat grain remains as bran, middlings, etc. Since the annual consumption of wheat in this country is about 6 bushels, or 360 lbs., for each person, the by-products amount to about 90 lbs. for each person, not including the amount resulting from the wheat milled for export.

217. Feeding bread.—When available, the stale bread from bakeries is used for feeding animals, especially horses. Gay[12] states that a Philadelphia teamster fed stale bread mixed with molasses, at a considerable saving and with entire success. An English writer[13] also reports good results from feeding bread to cab horses in London, the only trouble being that many loaves were consumed by the workmen.

218. Wheat bran.—Bran, which consists almost entirely of the coarse outer coatings of the wheat kernel, is fairly rich in digestible crude protein, containing 12.5 per ct. It has twice as much fat as the wheat grain but it is a light, bulky feed and contains nearly 10 per ct. of fiber. It is therefore lower in total digestible nutrients or in net energy than such concentrated feeds as corn, gluten feed, or linseed meal. However, for dairy cows, to which wheat bran is mostly fed, it has a somewhat higher value than is indicated by its yield of total digestible nutrients or of net energy. This is probably due to the fact that it is a very palatable feed, and moreover that it has a mild laxative effect. This laxative effect has been found by Hart and Patten[14] to be due to an organic phosphorus-containing compound called phytin, which forms 6 to 7 per ct. of bran. Previously it was supposed that the laxative effect was caused by the mild irritation produced by the chaffy bran particles on the lining of the intestinal tract. The best grades of bran have large, clean flakes and contain no screenings. (**222**) Spring wheat bran is usually slightly higher in fiber than that from winter wheat.

Bran from mills lacking machinery for perfect separation of the starch from the bran coats is somewhat lower in crude protein and fiber and higher in carbohydrates than the bran from the large mills. Such "country mill bran" sometimes sells for a slightly higher price than bran from which the flour has been more completely extracted.

Due to the fact that bran is low in lime, when animals are fed heavy allowances of bran or other wheat products along with other feeds also low in lime, trouble may result from a deficiency of this mineral constituent.[15] (**98**) For instance, horses heavily fed on wheat bran or

[12]Productive Horse Husbandry, p. 239. [14]N. Y. (Geneva) Bul. 250.
[13]The Field, England, July 15, 1893. [15]Hart, Wis. Bul. 287.

middlings sometimes suffer from "bran disease,"[16] which seriously affects their bones. Therefore, whenever a large allowance of bran is fed, it is important that plenty of lime be furnished in the ration, either thru using legume roughage, such as alfalfa or clover, or by adding lime in such forms as ground lime stone, wood ashes, bone meal, or ground rock phosphate (floats).

Knowing the properties of bran, one is in position to use this most valuable feed advantageously. As bran is ordinarily too expensive to be used as the sole concentrate for farm animals, it should be mixed with other concentrates to lighten the ration or add bulk, while improving its nutritive qualities. Fairly high in protein and rich in phosphorus, it serves its highest purpose in giving virility to the animal and in helping build bone and muscle without tending to fatten, thus being especially suited to young animals whose digestive capacities are sufficiently developed for this bulky feed. (**523, 681, 894**) Both on account of its high content of crude protein and phosphorus and because of its laxative action, bran is of great value for pregnant mares, cows, ewes, and sows. (**514, 662-3, 883, 1018**)

Bran is a most excellent feed for the dairy cow, being slightly laxative, giving bulk to the ration, and providing the crude protein and phosphorus so vital to the formation of milk. (**588**) It is a useful feed for horses, especially on idle days, because of its bulk and its laxative effect. It is frequently supplied at least once a week in the form of a bran mash, wet or steamed. Bran is too bulky a feed and too laxative to form a large part of the ration for horses at hard work. (**456, 485**) Being bulky, bran is often mixed with corn and other heavy concentrates for starting fattening cattle or sheep on feed. (**756, 856**) Tho too bulky for pigs, it is often used as part of the ration for brood sows. (**972, 1018**)

Due to its widespread popularity, bran is sometimes high in price compared with other nitrogenous concentrates which can be used with equally good results and many of which carry more protein than does bran.

219. Red dog flour.—Red dog flour, or dark feeding flour, generally contains considerable of the wheat germs and is therefore rich in crude protein and fat. Such flour differs but little in composition and feeding value from the best flour middlings. (**971**)

220. Wheat middlings.—Middlings vary in quality from red dog flour, which contains considerable flour, to standard middlings, or shorts, which may contain but little flour. To some extent *standard* or *brown middlings* and *shorts* are interchangeable terms. Standard wheat middlings should comprise the finer bran particles with a little flour adhering and with portions of the germs. Sometimes there are added ground-over bran and the sweepings and dirt of the mills, along with ground or unground weed seeds. *Flour* or *white middlings* are of somewhat higher grade than standard middlings, containing considerable low-grade flour and carrying slightly more crude protein and less fiber. Because flour middlings are

[16]Law's Vet. Medicine, III, p. 572.

richer in both protein and total digestible nutrients, they are worth at least 13 per ct. more than standard middlings. Middlings are useful with swine of all ages, but middlings alone do not make an efficient supplement to the cereals for pigs not on pasture. Dairy by-products or tankage should be fed along with middlings and grain to such pigs.[17] (969-70)

When fed as part of a suitable concentrate mixture, wheat middlings are satisfactory for dairy cows, but bran is commonly preferred. (589) Middlings and shorts alone should never be fed to horses, since they are too heavy and pasty in character and are liable to induce colic. (486) Like bran, both middlings and shorts are low in lime, which should always be supplied by the other feeds in the ration.

221. Wheat mixed feed.—*Wheat mixed feed,* or *shipstuff,* is strictly speaking, the entire mill run of the residues of the wheat kernel left after separating the commercial flour. The term is also used for various mixtures of bran and red dog flour or middlings. On the average, wheat mixed feed is worth 5 to 10 per ct. more than wheat bran, but the value varies, depending on how much red dog flour and middlings it contains.

222. Screenings.—In cleaning and grading wheat at the elevators and mills, there remain great quantities of screenings, consisting of broken and shrunken wheat kernels having a high feeding value, mixed with weed seeds. Many of the latter are nutritious, while others are of little worth, and a few actually poisonous. Poisonous seeds, such as corn cockle, are rarely present in screenings in sufficient quantities to cause ill effects. Unground screenings will never be used by farmers who seek to keep their land free from noxious weeds, for many such seeds will pass thru the animals uninjured and be carried to the field in the manure. Finely ground screenings are free from this objection. Screenings have their place and use, tho, because of their variable character, little of a definite nature can be said concerning them. (850, 954) Along with molasses and the by-products of the distilleries, breweries, flouring mills, oatmeal factories, etc., they are now largely absorbed in the manufacture of proprietary feeding stuffs. (288)

The feed control laws of various states require that when screenings are present in feeds the fact be indicated on the label and in some cases the percentage must be stated. *Wheat bran with mill run screenings* is a trade term for pure wheat bran plus the screenings which were separated from the wheat whence the bran originated. *Wheat bran with screenings not exceeding mill run* may be either wheat bran with the whole mill run of screenings or with but a portion of the screenings output.

III. Oats and their By-products

Next to corn, oats, *Avena sativa,* are the most extensively grown cereal in America. In the southern portion of our country a bushel of oats often weighs only 20 lbs., while on the Pacific coast it may weigh 50 lbs.

[17] Morrison and Bohstedt, Wis. Bul. 323, pp. 8-10.

Southern oats have a larger kernel than the northern grain, but bear an inflated husk carrying an awn or beard, which causes the grains to lie loosely in the measure. In the North the kernel is encased in a compact hull, usually not awned. The hulls of oats constitute from 20 to 45 per ct. of their total weight, the average being about 30 per ct. "Clipped oats" have had the hulls clipped at the pointed end, thereby increasing the weight per bushel. A hulless oat, but little grown in this country, serves well for poultry and swine, while the varieties with hulls are preferable for other stock. The oat grain is higher in crude protein than is corn, while in fat it exceeds wheat and nearly equals corn.

223. Oats as a feed.—Oats are the safest of all feeds for the horse, for the hull gives them such volume that the animal rarely suffers from gorging; in this respect they are in strong contrast with corn. On account of the mettle so characteristic of the oat-fed horse, it was long held that there is a stimulating substance in the oat grain. All claims of the discovery of this compound have, however, melted away on careful examination, and rations containing no oats have given results in every way as good as where oats were fed. (**473-4**) For dairy cows there is no better grain than oats, but the price of oats is often relatively high. (**579**) Oats mixed with other concentrates are helpful in starting fattening cattle or sheep on feed. As fattening progresses more concentrated feeds are usually substituted for all or most of the oats, because oats are much inferior to corn for fattening animals. (**740, 851**) Ground oats with the hulls sifted out provide a nourishing and wholesome feed for young calves and pigs. (**946**) For breeding swine, whole oats in limited quantity are always in place. As light weight oats contain more hull and less kernel than plump, heavy oats, their feeding value per pound will be correspondingly less.

In recent years the bleaching of low-grade oats and barley with sulfurous acid fumes to whiten the grain and raise the market grade, has become common. Smith[18] estimates that in a 6-months period, beginning in October, nearly 19,000,000 bushels of oats and barley were bleached at 13 grain centers in 3 north-central states. No feeding trials have been reported in which *bleached oats* have been fed, but complaints of injurious effects on the health of horses fed such oats are not uncommon. Several states have laws regulating the sale of bleached grains.

224. Oat by-products.—In the manufacture of oatmeal and other breakfast foods, after the light-weight grains are screened out to be sold as feed, the hulls are removed from the remainder, a vast quantity resulting. So completely are the kernels separated that the chaff-like hulls have but low feeding value. Oat hulls contain about 30 per ct. fiber, as Appendix Table I shows, and their feeding value is only little, if any, above that of oat straw. If fragments of the kernels adhere, their value is of course thereby improved. The oat hulls are sold in mixture with other feeds under various names. (**288**) The statement of feed manu-

[18]U. S. Dept. Agr., Bur. Plant Indus., Bul. 74.

facturers that the addition of a limited amount of hulls to a heavy concentrate mixture is beneficial seems reasonable in view of the excellent results secured with the natural unhulled oats. However, the appearance of such feeds is no guide to their value or the quantity of hulls present, and they hence should be purchased only on guarantee and on the basis of their actual composition compared with standard feeds.

After the oats are hulled, the fuzzy material covering the kernels is removed, and the kernels, or groats, are rolled or otherwise prepared for human consumption. The fuzzy material was formerly known as *oat dust,* but now the term *oat shorts* is applied to this material plus considerable portions of the fine floury part of the kernels removed in the milling process. *Oat middlings* are the floury portions of the kernels obtained in the milling of rolled oats. Commonly these by-products are used in the manufacture of mixed feeds, or they are combined with more or less of the hulls and sold as *oat feed.* The composition and value of oat feeds vary widely, depending on the amount of hulls present. These feeds should therefore be purchased only on guarantee of composition and from reputable dealers. The fiber content of any lot indicates the relative amount of hulls contained. (**627**)

Clipped oat by-product, or *oat clippings,* is the by-product obtained in the manufacture of clipped oats. This product, which consists of chaffy material broken from the ends of the hulls, empty hulls, light weight oats, and dust, is used in various proprietary feeds.

225. Ground corn and oats.—This feed, variously called *ground corn and oats, ground feed,* and *provender,* is extensively employed in the eastern and southern states for feeding dairy cows and especially horses. In composition it ranges from a straight mixture of good-grade corn and oats to one containing a large proportion of low-grade materials, such as oat hulls, ground corn cobs, and other refuse. The best guide to the purity of this feed is the fiber content. As corn contains only 2.0 per ct. fiber and oats 10.9 per ct., when ground corn and oat feed contains over about 7 per ct. fiber, it has either been adulterated or was made from poor quality oats. Where more than 9 per ct. fiber is present, adulteration is certain.[19] This feed should be purchased only on guarantee and from reliable dealers.

IV. Barley and its By-products in Brewing

Barley, *Hordeum sativum,* is the most widely cultivated of the cereals, growing as far north as 65° north latitude in Alaska and flourishing beside orange groves in California. Once the chief bread plant of many ancient nations, it is now used almost wholly for brewing, pearling, and stock feeding. Richardson[20] found that Dakota barley contained the highest percentage of crude protein, and Oregon barley the lowest. The adherent hull of the grain of ordinary brewing barley or of Scotch barley constitutes about 15 per ct. of its total weight.

[19]Woll and Strowd, Wis. Cir. 47. [20]U. S. Dept. Agr., Div. of Chem., Bul. 9.

California feed barley, grown extensively in some sections of the West, has more hull and weighs 45 lbs. or less per bushel; while the usual weight of common barley is 48 lbs. Hulless barley, which is often grown in the western states, has hard kernels, contains less fiber, owing to the absence of the hull, and is as heavy as wheat. (848) Barley has less digestible crude protein than oats, but more than corn. The carbohydrates exceed those of oats and fall below those in corn, while the oil content is lower than in either of these grains.

226. Barley as a feed.—On the Pacific slope, where corn or oats do not flourish in equal degree, barley is extensively used as a feed for animals. Thruout the northern states, except on the lighter soils, barley commonly yields more pounds of grain per acre than does oats. Since the feeding value of barley is as high or even higher than oats, pound for pound, the acreage of the high-yielding pedigree varieties of barley should be greatly increased where they thrive, and the grain used instead of oats for stock. Owing to the fact that a considerable part of the barley produced in many districts has in the past been used for malting and brewing, many farmers do not appreciate its value for stock feeding.

The horses of California are quite generally fed on crushed barley, with wheat, oat, or barley hay for roughage. Crushed or ground barley is even better than oats, pound for pound, for work horses, while whole barley is worth slightly less than whole oats. (478) Barley is the common feed for dairy cows in northern Europe. The Danes sow barley and oats together in the proportion of 1 part of barley to 2 of oats, the ground mixed grain from this crop being regarded as the best available feed for dairy cows and other stock. At the Wisconsin Station[21] ground barley has proved fully equal, pound for pound, to ground corn for dairy cows. (580) As barley contains much less hull than oats, it is a more concentrated grain and better suited for feeding fattening cattle, sheep, and pigs. Fed with legume hay to fattening steers and lambs, barley has given entirely satisfactory results. (738, 848) In Great Britain and northern Europe barley takes the place of corn for pig feeding, leading all grains in producing pork of fine quality. In American trials good northern-grown barley, when ground, was worth 5 per ct. less than corn for pigs. (944) Owing to its more chaffy nature, California feed barley is somewhat lower in value than common barley. (848) Tho barley is somewhat higher than corn in crude protein, it is still decidedly carbonaceous in character, and should be fed with legume hay or with a nitrogenous concentrate for the best results. The protein of barley is also unbalanced in composition, like that of corn, wheat, and the other cereals. Due to this, in feeding pigs without pasture better results are secured when barley is supplemented with dairy by-products or tankage than when fed with middlings or linseed meal. (118, 944)

227. Malt.—In making malt the barley grains are first steeped in warm water until soft. The grain is then held at a warm temperature until

[21]Morrison, Humphrey, and Hulce, Bul. 319, p. 68.

HEADS OF DIFFERENT TYPES OF WHEAT

From left to right: 1, bearded winter wheat (Turkey Red); 2, beardless spring wheat (Blue Stem); 3, bearded spring wheat (Velvet Chaff); 4, Durum, or macaroni wheat; 5, club wheat.

HEADS OF OATS, EMMER, AND SPELT

From left to right: 1, variety of oats with open or spreading panicle; 2, side oats; 3, emmer; 4, spelt.

A Fine Oat Field Ready for Harvesting

Next to corn, oats are the most extensively grown of all the cereals in America. The grain is unexcelled for horses and is widely used for other stock, especially dairy cattle and sheep.

Heads of Different Varieties of Barley and of Rye

From left to right: 1, two-rowed barley; 2, common six-rowed barley, or so-called four-rowed barley; 3, true six-rowed barley; 4, California feed barley; 5, beardless barley; 6, rye.

it begins to sprout, in which process the amount of diastase, the enzyme which converts starch into malt sugar, increases greatly, and some of the starch in the grain is acted on by the diastase. When sufficient diastase has been formed in the sprouting grain, it is quickly dried. The tiny, dry, shriveled sprouts are then separated from the grains, and put on the market as *malt sprouts*. The dried grains remaining form *malt*. In the manufacture of beer the malt, after being crushed by rolling, is moistened and usually mixed with cracked corn which has been cooked. The diastase in the malt now converts most of the starch in the corn and the malt itself into malt sugar. This, together with some of the nitrogenous and mineral matter, is then extracted from the mass and fermented by yeast. The freshly extracted residue constitutes *wet brewers' grains*, which are usually dried and sold as *dried brewers' grains* or *brewers' dried grains*.

It was formerly claimed that malting barley increased its value for stock feeding. Investigations by Lawes and Gilbert of the Rothamsted Station,[22] England, show that a given weight of barley is of greater value for dairy cows and fattening animals than the amount of malt and malt sprouts that would be produced from it. This is due to the oxidizing or burning up of some of the stored nutrients in the grain during the sprouting process. Malt is, however, very palatable to stock, and useful as a conditioner and in fitting animals for exhibition or sale.[23]

228. Dried brewers' grains.—Dried brewers' grains, which are no more perishable than wheat bran, contain over 70 per ct. more digestible crude protein and twice as much fat as wheat bran, but are lower in carbohydrates, which are largely pentosans.[24] (**9**)

Higher in fiber than wheat bran, they are a bulky feed, and therefore not well suited to pigs. They have been widely fed to dairy cows and serve well as part of the concentrate allowance for horses, especially for those at hard work and needing ample protein. (**489, 593, 759, 856**)

229. Wet brewers' grains.—Owing to their volume, watery nature, and perishable character, wet brewers' grains are usually fed near the brewery. Containing about 75 per ct. water, they have slightly over one-fourth the feeding value of an equal weight of dried grains. Supplied in reasonable quantity, 20 to 30 lbs. per head daily, and fed while fresh in clean, water-tight boxes and along with nutritious hay and other roughage, wet brewers' grains give good results with dairy cows. They are also good for fattening cattle and swine when used with dry feed and furnishing not over half the nutrients in the ration. On account of their "washy" nature, horses should not be fed over 20 lbs. per head daily and fattening sheep not over 1 lb. daily per 100 lbs. live weight.[25]

230. Malt sprouts.—The tiny, shriveled sprouts which have been separated from the dried malt grains form a bulky feed which is rather

[22]Rothamsted Memoirs, Vol. IV.
[23]Pott, Handb. Ernähr. u. Futter, III, 1909, p. 257.
[24]Mass. (Hatch) Bul. 94.
[25]Pott, loc. cit., p. 233.

low in carbohydrates and fat, but carries about 20 per ct. digestible crude protein, one-third of which is amids.[26] At former prices they were often an economical source of protein, but since they are not relished by stock, they should be given in limited quantity mixed with other concentrates. Malt sprouts are especially valuable for dairy cows, tho they will not usually eat over 2 or 3 lbs. daily. (**594**) In Europe horses have been fed as high as 5 to 6 lbs. per head daily with good results, and sheep 0.5 lb. daily per 100 lbs. live weight. Since malt sprouts swell greatly when they absorb water, they may cause digestive disturbances if fed dry to stock in large amounts and should therefore be soaked for several hours before feeding. When not over 1 lb. per head is fed to cattle with other feed, soaking is unnecessary, but moistening to lay the dust is advisable.[27]

231. Barley feed; barley bran.—*Barley feed* is the entire mill run by-product from the manufacture of pearl barley or barley flour, and includes the hull as well as the outer coat of the kernel. Usually there is but a small amount of this feed available, but during the war, when large quantities of barley were milled for flour, large amounts of barley feed were sold. A good grade of barley feed, containing 11 per ct. fiber, was found by Morrison, Humphrey, and Bohstedt at the Wisconsin Station[28] to be worth about $42.16 per ton for dairy cows compared with wheat bran at $45 per ton. For fattening pigs, barley feed was worth 17 per ct. less per ton than ground barley. *Barley bran* is rather erroneously named, as it consists almost entirely of barley hulls, with only a small amount of the outer coat of the kernel proper. At the Wisconsin Station, barley bran containing 27 per ct. crude fiber was worth only $29.56 per ton for dairy cows compared with wheat bran at $45.00.

V. Rye and its By-products

Rye, *Secale cereale,* the principal cereal of north Europe, is not extensively grown in America. Tho it repays good treatment, this "grain of poverty" thrives in cool regions on land that would not give profitable returns with the other cereals. It furnishes about one-third of the people of Europe with bread, and when low in price or off-grade is commonly fed to stock. (**396**)

232. Rye and its by-products.—Tho farm animals show no fondness for rye, they take it willingly when mixed with other feeds, as should usually be done. Fed alone or in large amounts, it is more apt to cause digestive disturbances than the other cereals. In northern Europe it is a common feed for horses and swine. (**480, 948**) Fed in large allowances to cows, rye produces a hard, dry butter, but a limited amount mixed with other feeds has given good results. (**581**)

The by-products in the manufacture of rye flour are *rye bran* and *rye middlings,* which are usually combined and sold as *rye feed.* All have about the same feeding value as the corresponding wheat feeds, each con-

[26]Pott, loc., cit., pp. 223. [27]Pot, loc. cit., p. 226. [28]Unpublished data.

taining less fiber and being somewhat lower in protein and higher in nitrogen-free extract than the corresponding wheat feed.

VI. Emmer; Spelt

Emmer, *Triticum sat.*, var. *dicoccum*, often incorrectly called "spelt" or "speltz," was introduced into America from Germany and Russia. It is a member of the wheat family, altho in appearance the grain resembles barley. Being drought resisting, emmer is of value in some of the semi-arid regions of America. Emmer is grown chiefly in the northern plains states, the average yield per acre being about 22 bushels of 40 lbs. each. The adherent hulls of emmer represent about 21 per ct. and the kernels 79 per ct. of the grain.

The following table shows the average yields of various spring grains grown without irrigation for 8 years at the North Dakota Station at Fargo,[29] for 5 years at the North Platte, Nebraska, Station,[30] and for 10 years at the South Dakota Station at Brookings.[31]

Yield of emmer compared with other spring grains

Grain	North Dakota Yield per acre Lbs.	Nebraska Yield per acre Lbs.	South Dakota Yield per acre Lbs.
Emmer	1,945	1,142	1,868
Barley	1,877	1,423	2,286
Oats	1,969	1,032	2,142
Wheat	1,711	....	....
Durum wheat	1,835*	1,151	1,100

*Av. of 7 years.

While emmer outyielded all the other cereals except oats in the North Dakota trials, at the other stations it was considerably excelled by other grains. Before planting any large acreage, one should therefore find out whether the yield compares favorably with the other cereals in that particular section. Winter emmer, introduced more recently into the United States, is of considerable promise in states where it is hardy.[32]

Spelt, *Triticum spelta,* another relative of the common wheat, is little grown in this country and has been largely displaced by other grains where once grown in Europe. The grain resembles emmer in composition and feeding value.

233. Emmer as a feed.—In composition emmer closely resembles oats. Like that grain it is somewhat bulky to use as the sole concentrate for fattening animals, and gives better results when mixed with corn or barley. (**852**) Tho its value is usually somewhat lower than that of corn, with corn silage and linseed meal ground emmer proved equal to corn, pound for pound, with fattening steers in a trial at the South Dakota Station. (**743**) With dairy cows and fattening pigs its value is somewhat less than that of corn. (**582, 947**)

[29] N. D. Bul. 75.
[30] Nebr. Bul. 135.
[31] S. D. Bul. 179.
[32] U. S. Dept. Agr., Farmers' Bul. 466.

CHAPTER X

MINOR CEREALS, OIL-BEARING AND LEGUMINOUS SEEDS AND THEIR BY-PRODUCTS

I. Rice and its By-products

The production of rice, *Oryza sativa,* is steadily increasing in Louisiana, Texas, Arkansas, and California, where it already forms an important industry. In 1921 about 34,724,000 bushels of rice, over 99 per ct. of the entire crop of the United States, was produced in these states.[1] Like wheat, this cereal is used almost entirely for human food, only the by-products from the manufacture of polished rice (table rice) being fed to farm animals.

234. Rice and its by-products.—In preparing *rough rice,* often called *paddy,* for human food, first the hulls are removed and next the *rice bran,* consisting of the germ and the outer skin of the kernel. The kernels are then "polished," both to separate the creamy outside layer of cells, rich in crude protein and fat, and to produce an attractive, pearly luster. The resulting floury particles form *rice polish.* A "barrel" of rough rice, weighing 162 lbs., will yield about 101 to 106 lbs. of polished rice, 4 to 6 lbs. of rice polish, 13 to 22 lbs. of rice bran, and 29 to 34 lbs. of hulls, with a wastage of 3 to 5 lbs.[2]

Rice hulls are tasteless, tough, and woody. They are heavily charged with silica, or sand, and have sharp, roughened, flinty edges and needle-like points. It has been claimed that they are irritating and dangerous to the walls of the stomach and intestines.[3] They are digested to only a small extent by animals, and furnish but about one-third as much digestible nutrients as wheat straw. They should therefore never be fed to farm animals. Yet they have been extensively used by unscrupulous dealers for adulterating mixed feeds, and are sometimes ground and sold as "husk meal" or "Star bran."

Rice bran when pure is composed of the outer layer of the rice kernel proper, together with the germs, and a small amount of hulls not separated in the milling process. This feed, when adulterated with hulls, is called "commercial bran." Unadulterated bran, which contains only about 12 per ct. fiber, is a highly nutritious feed, as not enough hulls are present to be injurious. It contains about 11 per ct. fat, and approximately as much protein as barley or wheat, but less nitrogen-free extract. As rice oil, or fat, soon becomes rancid, the bran is frequently distasteful to animals. The Louisiana Station employed rice bran successfully as half the concentrates for horses and mules, and it was found satisfactory

[1]U. S. Dept. Agr. Crop Reporter. [2]Tex. Bul. 191. [3]La. Bul. 77.

for fattening steers at the Texas Station. (**745**) Fed to dairy cows and swine in large amounts, even when not rancid, it injures the quality of milk and produces soft pork. (**955**)

Rice polish, which has a feeding value equal to corn, carries slightly more crude protein and considerably more fat, but correspondingly less nitrogen-free extract. It is used chiefly for feeding swine and cattle. (**745, 955**)

Only low-grade *rough rice* and *hulled rice* are commonly fed to stock. Dodson of the Louisiana Station[4] values rough rice at 7 and hulled rice at 16 per ct. more than corn. Hulled rice is the richest of all cereals in carbohydrates, but relatively low in crude protein and fat. Since no ill effects from the hulls have been known to follow the feeding of rough rice, it may replace corn in the rations of farm animals. On account of the hardness of the kernels it gives better results when ground. The Texas Station[5] found that ground damaged rice had about half the value of cottonseed meal for fattening steers. Red rice, a pest in rice fields, equals the cultivated grain in feeding value. (**745**)

II. Sorghums and Millets

Numberless millions of people in India, China, and Africa rely on the sorghums and millets for their bread. Church[6] tells us that 33,000,000 acres of land in India are annually devoted to growing the millets and the sorghums including the kafirs, milos, etc.—a greater area, he reports, than is devoted to wheat, rice, and Indian corn combined. Ball[7] writes that thruout Africa—on the dry plains, in the oases of the Sahara, on high plateaus, in mountain valleys, and in tropical jungles—the sorghums are the one ever-present crop. Their forms are as diverse as the conditions under which they grow, the plants ranging in height from 3 to 20 feet, with heads of different shapes varying from 5 to 25 inches in length.

The sorghums, *Andropogon sorghum* or *Sorghum vulgare,* vars., may be divided into two classes—the saccharine sorghums, having stems filled with sweet juices, and the non-saccharine varieties, with more pithy stems and juice sour or only slightly sweet. The Indian corn plant never gives satisfactory returns if once its growth is checked. The sorghums may cease growing and their leaves shrivel during periods of excessive heat and drought; yet when these conditions pass and the soil becomes moist again, they quickly resume growth. This quality gives to this group of plants great worth and vast importance as grain crops for the southern portion of the semi-arid plains region. Their value in this section is well shown by the fact that between 1899 and 1921 the acreage in the United States of grain sorghums increased from 266,000 to 4,652,000 acres, the yield of grain in 1921 being 115,110,000 bushels.

[4]La. Planter, 44, 6, p. 92.
[5]Tex. Bul. 86.
[6]Food Grains in India, 1901.
[7]Yearbook, U. S. Dept. Agr., 1913.

235. Grain sorghums.—The non-saccharine sorghums, or grain sorghums, include *kafir, milo, feterita, kaoliang,* and the less important *durra* and *shallu.* Kafir and milo are the most widely grown in the United States. Most of the grain sorghum produced in the United States is grown in the southern part of the Great Plains region, east of the Rocky Mountains, extending from southwestern Nebraska to northwestern Texas. A limited amount is also grown in sections of Arizona, Utah, and California. By selection and crossing, varieties of sorghum have been developed which are suited to the various districts, especially dwarf strains which have erect heads that are easily harvested with the grain header, and which are early maturing, thus escaping late summer droughts. Thru the development of early types the sorghums are also being carried farther north.

Thruout most of the western portion of the grain-sorghum belt, these crops are more sure than corn, due to their drought resistant qualities, and even on good soil usually give larger yields. Even in central and eastern Kansas and Oklahoma, the sorghums are superior to corn on poor, thin uplands. Churchill and Wright[8] of the Oklahoma Station report that on soil underlaid by hardpan, where the average yield of corn during a 5-year period was only 1 bushel per acre, kafir averaged 34.9 bushels. Even on the better land in the eastern part of the grain sorghum belt, it is advisable to replace some of the corn acreage with grain sorghum as an insurance against severe drought.

The average yield of the grain sorghums in the United States has ranged from 27 bushels per acre in good seasons to 11 or 12 bushels in times of drought. Yields as high as 75 to 80 bushels per acre are secured under very favorable conditions. The customary basis for selling the seed of the grain sorghums is by the 56-lb. bushel, but, according to Churchill and Wright, the usual weight is about 54 pounds. Kafir heads contain about 77 per ct. of grain and those of milo about 84 per ct.; accordingly 73 lbs. of head kafir and 66 lbs. of head milo are required for a bushel (56 lbs.) of grain. Ball[9] states that altho the percentage of grain in the entire crop varies widely with the season and thickness of stand, under ordinary conditions from 35 to 40 per ct. of the air-dry weight of a crop of milo and kaoliang and 25 per ct. of kafir will be grain.

When cut for grain the crop should not be harvested until the seeds are well matured. Because the hard-coated seeds when apparently dry may contain much water, the grain sorghums are especially apt to heat in the bin unless precautions are taken.

236. Grain sorghums as feeds.—The different sorghums are similar in composition, carrying about as much nitrogen-free extract as corn, slightly more crude protein, and 1.5 to 2.0 per ct. less fat. Supplemented with protein-rich feeds, they are excellent for all classes of animals. The grain sorghums are well liked by stock, tho they are somewhat less palatable than corn. Their feeding value averages about 90 per ct. that

[8]Okla. Bul. 102. [9]U. S. D. A. Farmers' Bul. 448.

of corn per pound. (741-2, 853, 949-51) For horses, fattening cattle, dairy cows, and pigs the grain is usually ground, being then called "chop." Grinding for sheep is not essential. Often the unthreshed heads are fed, or the forage carrying the heads is supplied, especially to idle horses, colts, and young stock. (481) The product obtained by grinding the entire heads, called "head chop," resembles corn-and-cob meal in composition.

237. Kafir.—In the United States the kafirs lead among the grain sorghums in both grain and forage production. They are stout-stemmed, broad-leaved plants, having quite juicy stalks and long, erect, compact, cylindrical heads carrying small egg-shaped seeds. They do not sucker or produce undesirable side branches, nor do they lodge or shatter the grain. Since most of the kafirs are rather late in maturing, they are grown chiefly in the more humid sections of the grain-sorghum belt, especially eastern Kansas and Oklahoma. The most common variety in these districts is the Blackhull, while more dwarf varieties, which are earlier, give better yields farther west. (481, 583, 681, 741, 853, 949)

238. Milo.—The milos have few leaves compared with the kafirs and the stalks have little juice. Therefore, milo is not as valuable as kafir for forage. Milo is earlier in maturing and hence is usually a more reliable grain crop in the drier sections. The seeds are larger and flat, and are borne in short, thick heads, which are often goose-necked or drooping. In order to make harvesting easier, strains have recently been developed in which nearly all the heads are erect. Milo is fully equal to kafir in feeding value. (481, 742, 853, 950)

239. Feterita.—Feterita, or Sudan durra, usually has slender stems carrying more leaves than milo, but less than kafir, and erect heads bearing flattened seeds. It ripens with milo, but when planted late matures sooner. It yields as much grain as kafir, tho less forage, and is a promising sorghum for the western part of the grain-sorghum belt. Unimproved feterita lodges badly after maturity, but a more dwarf, improved type developed at the Texas Station[10] is free from this fault.

240. Kaoliang; durra; shallu.—The *kaoliangs* are early-maturing sorghums introduced from northern China. They are slender, dry-stemmed plants, with loose, open, erect heads. They are grown chiefly in the northern plains section where the other types will not mature. In other sections milo, kafir, or feterita usually outyield kaoliang in yield of grain. The forage of kaoliang is scanty and of poor quality, the stalks being pithy and the leaves few. (951)

The true *durras* were the first grain sorghums introduced into the United States. They were never grown to any great extent, as they have coarse stems and relatively few leaves, and also because they lodge readily and sucker badly. The grain shatters easily and the pendent, or "goose-necked," heads make harvesting difficult.

[10]Tex. Bul. 275.

Shallu, or "Egyptian wheat," is slender-stemmed, with low, spreading heads which shatter badly. Reports from various experiment stations show that shallu is of little value compared with the other sorghums.

241. Sweet sorghums.—The sweet sorghums, or *sorghos,* often called "cane" by farmers, are forage rather than grain producers, and are therefore discussed more fully in Chapter XII. (**308-9**) Early varieties will mature wherever corn ripens. The seed of sweet sorghum contains considerable tannin, which makes it astringent. Its feeding value is only about two-thirds as much per pound as seed from the grain sorghums. For grain production sweet sorghum is surpassed by corn in the humid regions and by the grain sorghums in the plains districts.

Darso, a dwarf, early maturing variety of sorghum introduced by the Oklahoma Station,[11] has some of the characteristics of both the sweet sorghums and the grain sorghums. The stalk is sweet and juicy, while the grain is similar in composition to kafir.

242. Broom corn.—In harvesting broom corn the heads are cut before the seed has fully matured, and the seed is removed from the brush before it is thoroly dry. This seed has feeding value and may be saved by drying or ensiling.

243. Millets.—The millets chiefly grown in this country are: (1) the foxtail millets, *Setaria Italica* spp., all resembling common foxtail or pigeon grass in appearance; and (2) the proso, hog, or broom corn millets, *Panicum miliaceum* spp., which have spreading or panicled heads, wide hairy leaves, and large seed. The latter are the common millets of the Old World, which have been raised since prehistoric times in certain districts as an important grain crop for human food. The value of the various types of millet for forage is discussed in Chapter XIII.

Millet is not raised to any large extent for grain in this country except in the northern plains district, where the growing season is too short for the sorghums. Here it is grown chiefly as a late-sown catch crop, for other cereals will usually outyield it if seeded at the normal time. As a general rule proso yields 10 to 30 bushels per acre.[12] Attempts have been made to exploit proso fraudulently as a very high-yielding dry land crop. In trials covering 6 to 7 years at the Highmore, South Dakota, Station, various types of proso millet averaged 16.4 bushels per acre and varieties of foxtail millets 20.7 bushels.[13] Wilson and Skinner found proso satisfactory for beef cattle, sheep, and swine at the South Dakota Station,[14] but more grain was required for 100 pounds gain than when corn was fed. The pork from millet-fed pigs was of good quality. (**744, 854, 952**) Millet seed should be ground for all classes of stock.

[11]Okla. Bul. 127.
[12]U. S. D. A. Farmers' Bul. 1162.
[13]S. D. Bul. 135.
[14]S. D. Buls. 83, 86, 97.

CUTTING RICE WITH A BINDER IN CALIFORNIA

Rice is usually grown on low, level ground under irrigation. Before harvest the water is drained from the land, so the soil will become firm. (From U. S. Department of Agriculture.)

HEADS OF DIFFERENT TYPES OF GRAIN SORGHUMS

From left to right: 1 and 2, yellow milo; 3, white kaoliang; 4, brown kaoliang; 5, feterita; 6, red kafir; 7, pink kafir; 8, black-hulled kafir. (From *Breeder's Gazette.*)

PICKING A GOOD CROP OF COTTON

The United States produces the major part of the world's supply of cotton. Our exports of cotton fiber and the by-products of the crop—cottonseed cake or meal and cottonseed oil—far exceed in value those from any other crop or agricultural product. In the "cotton belt," cotton is by far the most important single crop. (Copyright photograph by Underwood & Underwood.)

III. Buckwheat and its By-products

Tho rarely used for feeding stock, buckwheat has a fair value for such purpose, its nutrients running somewhat lower than those in the leading cereals. (**953**)

244. Buckwheat by-products.—The black, woody hulls of the buckwheat grain, *Fagopyrum esculentum,* have little feeding value and should be used to give bulk or volume to the ration only when it cannot be otherwise secured. On the other hand, *buckwheat middlings,* that part of the kernel immediately under the hull, which is separated from the flour on milling, contain 28 per ct. crude protein and 7 per ct. fat, with little fiber, and hence have a high feeding value. The miller, desiring to dispose of as much of the hulls as possible, mixes them with the middlings to form *buckwheat bran* or *feed.* Woll[15] concludes that buckwheat feed, not over half of which is hulls, is worth about 20 per ct. less than wheat bran. Such feed carries about 16 per ct. protein and 24 per ct. fiber. The intelligent purchaser avoids the worthless hulls so far as he can, choosing instead the rich, floury middlings.

Buckwheat by-products are nearly always used for feeding cows, rightly having the reputation of producing a large flow of milk, but may be successfully fed in limited quantities to other farm animals. (**595**) The charge that buckwheat by-products make a white, tallowy butter and pork of low quality fails if they are not given in excess. When stored in bulk, buckwheat by-products are liable to heat unless first mixed with some light feed, like wheat bran. (**953**)

Occasionally buckwheat grain and also the green fodder or straw cause peculiar eruptions and intense itching of the skin. This affects only white or light-colored parts of the hide, and animals are subject to the disease only when exposed to the light.

IV. Oil-bearing Seeds and their By-products

The annual crop of cotton, *Gossypium hirsutum,* in the United States now amounts to about 11,000,000 bales of 500 lbs. each with approximately 5,000,000 tons of cotton seed as a by-product, since for 1 lb. of fiber, or lint, there are nearly 2 lbs. of seed. Previous to 1860 the seed of the cotton plant was largely wasted by the planters, who often allowed it to rot near the gin house, ignorant or careless of its worth, while meat and other animal products which might have been produced from it were purchased at high cost from northern farmers. The utilization of the cotton seed and its products as food for man and beast furnishes a striking example of what science is accomplishing for agriculture.

According to Fraps,[16] 1 ton of cotton seed yields approximately the following: Linters, or short fiber 69 lbs.; hulls, 579 lbs.; cake, or meal, 915 lbs.; crude oil, 299 lbs.; loss, etc., 138 lbs.

[15]Wis. Cir. 42.

[16]Texas Bul. 189.

245. Cotton seed.—The cotton seed carries about 19 per ct. fat, or oil, and nearly 20 per ct. crude protein. Formerly much seed was fed in the South, especially to steers and dairy cattle. (**598, 752**) Now little is fed before the oil is extracted, both on account of the value of the oil and because cottonseed meal usually gives better results. Burns of the Texas Station[17] found that 205 lbs. of cotton seed fed with cottonseed hulls and kafir grain was not equal to 100 lbs. of cottonseed meal for fattening steers. Owing to the high oil content, cotton seed sometimes has an unduly laxative effect. Wet, moldy cotton seed, or that which has heated, should never be fed.

246. Cottonseed cake and meal.—At the oil mills, after cotton seed has been cleaned and more or less of the short lint covering the seeds removed by machinery, the leathery hulls of the cotton seed are cut by machines, called hullers, so the kernels may drop out. The kernels are separated from the hulls by screens and are then crushed, heated, placed between cloths, and subjected to hydraulic pressure to remove the oil. The residue is a hard, yellowish, board-like cake about one-half inch thick, 14 in. wide, and 32 in. long. For the trade in the eastern and central states the cake is generally ground to a fine meal, for the western trade it is often broken into pieces of pea or nut size for cattle and coarsely ground for sheep, while the export cake is commonly left whole. For feeding out of doors the broken cake is preferable to meal, as it is not scattered by the wind. Unadulterated cottonseed meal of good quality should have a light yellow color and a sharp, nutty odor. A dark or dull color may be due to age, to adulteration with hulls, to overheating during the cooking process, or to fermentation—all these injure its value.[18]

Cottonseed meal is one of the richest of all feeds in protein and carries over 8 per ct. of fat. The protein and fiber content vary considerably, depending chiefly on how thoroly the hulls are removed from the meal. The value of fresh and wholesome meal depends on the percentage of protein it contains; manufacturers and feed control officials have therefore agreed on the following classification of products:

Choice cottonseed meal must be perfectly sound and sweet in odor, yellow, not brown or reddish, free from excess of lint, and must contain at least 41 per ct. of crude protein.

Prime cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 38.6 per ct. of crude protein.

Good cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 36 per ct. of crude protein.

Cottonseed feed is a mixture of cottonseed meal and cottonseed hulls, containing less than 36 per ct. crude protein.

Owing to its wide variation in composition, cottonseed meal should be purchased on guarantee whenever possible. During recent years, as the millers have found they can sell the lower grades of meal for nearly as high a price per ton as meal high in protein, many have removed the hulls less thoroly from the kernels, thereby producing meal lower in protein and higher in crude fiber than previously.[19] Northern farmers will usually find it most economical to purchase high-grade meal.

[17]Tex. Bul. 110. [18]Hills, Vt. Rpt. 1909. [19]Fraps, Tex. Buls. 189, 241.

247. Cottonseed feed.—On northern markets *cottonseed feed,* which may consist largely of hulls, is often sold for but a few dollars per ton less than choice cottonseed meal. By appearance alone it is impossible to distinguish good cottonseed meal from finely ground cottonseed feed. Cottonseed feed may be an entirely legitimate product, for it is impossible to separate thoroly the hulls of certain kinds of cotton seed from the kernels. However, such feed should be bought at a price corresponding to its crude-protein content.

In case of doubt as to purity, the following simple test will show the approximate amount of hulls present in cottonseed meal.[20]

Place a teaspoonful of the meal (do not use more) in a tumbler and pour over it from 1.5 to 2 ounces of hot water. Stir the mass till it is thoroly wet and all the particles are floating. Allow it to settle for 5 to 10 seconds and pour off the liquid. If there has settled out in this time a large amount of fine, brown sediment which is noticeably darker than the fine yellow meal and which keeps settling out on repeated treatments with hot water, the product is low grade. All meals contain small quantities of hulls and will show dark specks when thus tested, but the results are striking when pure meal is compared with cottonseed feed.

248. Cold-pressed cottonseed cake.—Cold-pressed cottonseed cake, or "caddo" cake, is produced by subjecting the entire uncrushed, unheated seed to great pressure. In the residual cake there is a larger proportion of hull to meal than in normal cake, with correspondingly lower feeding value. This product is usually sold in nut or pea size but is sometimes ground to a meal. The crude-protein content of cold-pressed cake is a reliable guide to its feeding value. (**598, 751, 855**)

249. The poison of cotton seed.—Cottonseed meal or even cotton seed can be fed with safety in limited amounts and in properly balanced rations to dairy cows, beef cattle, sheep, and horses. However, practical experience and scientific trials alike show that when injudiciously fed, animals are poisoned by these feeds. Cottonseed meal is most poisonous to swine. When cottonseed meal forms as much as one-third of the concentrates fed pigs, they thrive at first, but after a few weeks may become sick and die. Restricting the allowance of meal, keeping the animals on pasture, supplying succulent feeds, or souring the feed may help, as is discussed later (**974**), but no uniformly successful method of feeding cottonseed meal to swine has yet been found. Steers closely confined and heavily fed on cottonseed meal often are affected by the poison after a period of about 100 days. They have a staggering gait; some become blind, and death frequently ends their distress. Young calves are especially susceptible to the poison. Feeding allowances as small as one-fourth to one-half pound of cottonseed meal per head daily has proved fatal to calves.[21]

Numerous efforts have been made during the past 20 years to determine the cause of the poisonous effect of cottonseed meal. The harm has been variously ascribed to the lint, the oil, the high protein content, to a poisonous albumin or alkaloid, to cholin and betaine, to resin present

[20] Vt. Bul. 101. [21] N. C. Bul. 109.

in the meal, to decomposition products, and to salts of pyrophosphoric acid. Further work showed that the poisonous effects were not due to any of these causes. Recently Withers and Carruth of the North Carolina Station[22] have found that the poisonous quality is due to a yellow compound, called *gossypol,* which can be extracted from cotton seed by ether. The purified gossypol had the same poisonous effect as the cotton seed. This substance is destroyed to some extent by heating, and therefore cottonseed meal is less poisonous than raw cotton seed. It is to be hoped that in time methods may be developed of treating cottonseed meal so that it will be safe for all classes of animals.

250. Rational use of cottonseed meal and cake.—Cottonseed meal is one of the most valuable of feeds when rationally fed, often being the cheapest available source of protein, and thru it, of nitrogen for maintaining soil fertility. (**435**) The amounts which may be safely fed to each kind of stock are fully discussed in the respective chapters of Part III. The most extensive use of cottonseed meal is by dairymen, for comparatively heavy allowances may be fed to milk cows without harm. (**596**) Fed in large amount, cotton seed or cottonseed meal produces hard, tallowy butter, light in color and poor in flavor. A limited quantity has little effect on the butter and is even helpful with cows whose milk produces a soft butter.

For fattening steers and sheep cottonseed meal, in limited amount, is one of the most satisfactory of nitrogenous supplements. (**750, 855**) Great numbers of steers are fattened at the oil-mill factories, often on a ration of 6 to 8 lbs. of cottonseed meal with cottonseed hulls or corn silage for roughage. Harrington and Adriance at the Texas Station[23] found that cotton seed produced harder fat than corn, the kidney, caul, and body fat of steers fed cotton seed having melting points 4.1°, 3.2°, and 8.7° C. higher, respectively, than the corresponding fats of corn-fed steers. The effect was even more marked in the case of sheep. In restricted amounts, mixed preferably with bulky feed, cottonseed meal has been fed to horses and mules with entire success. (**488**) Altho cottonseed meal is especially poisonous to swine, some feeders, guided by experience, use it in small amounts and for short periods with little loss. (**974**)

Cottonseed meal having a dull color due to improper storage, and that from musty and fermented seed, should never be used for feeding stock. Cottonseed meal does not have the beneficial laxative effect of linseed meal, but instead is somewhat constipating. Much more care must be used in feeding it than in using linseed meal, but when carefully fed in proper combination with other feeds, as good results may be secured with horses, dairy cows, and fattening cattle and sheep as when linseed meal is employed. This most nutritious feed, the richest in fertilizing constituents of all our common feeding stuffs of plant origin, is often spread directly on the land as fertilizer. Obviously, its full value can be real-

[22] Jour. Agr. Res., 5, 1915, pp. 261-88; 12, 1918, pp. 83-102, 425-51. [23] Tex. Bul. 29.

ized only when the meal is first fed to animals and the resulting manure applied to the soil. (436) With increasing knowledge of the usefulness of this feed, it is to be hoped that instead of annually exporting one-fourth the cottonseed cake and meal produced to other countries, as has been done, all will be fed on American farms.

251. Cottonseed hulls.—Cottonseed hulls, which contain somewhat less digestible nutrients than oat straw, are extensively employed in the South as roughage for cattle feeding. The hulls are low in crude protein, of which but a small part is digestible. With only 0.3 lb. of digestible crude protein in 100 lbs. the hulls have the extraordinarily wide nutritive ratio of 1:122, the widest of any common feeding stuff. Obviously they should be used with feeds which are rich in protein. Fed with cottonseed meal to steers by Wilson at the Tennessee Station,[24] cottonseed hulls produced somewhat lower gains than corn silage, 100 lbs. of hulls replacing 170 lbs. of corn silage. (773) Because of their low palatability and digestibility, cottonseed hulls are not well suited to dairy cows, corn stover having a higher feeding value. (628)

Cottonseed hulls are usually fuzzy, due to short lint which remains on the seed. Sometimes this lint is removed from the seed at the oil-mills for paper making and other purposes and the hulls from such seed ground, being then called *cottonseed hull bran.* Tho finely ground, the value of the product is not appreciably greater than that of ordinary hulls.

252. Flax seed.—The average production in the United States of seed from the flax plant, *Linum usitatissimum,* from 1911 to 1920 was about 14,980,000 bushels of 56 lbs., over 95 per ct. of which was grown in Minnesota, the Dakotas, and Montana.[25] The reserve building material is stored in the flax seed largely as oil and pentosans, instead of as starch, which most seeds carry, no starch grains being found in well-matured flax seeds. On account of the high commercial value of the oil it contains, flax seed is rarely used for feeding stock other than calves. (681, 683)

The oil of the flax seed is either extracted by the "old process," thru crushing and pressure, as in the production of cottonseed oil, or it is dissolved out of the crushed seed with naphtha, the residue in either case being variously termed *linseed oil meal, linseed meal,* or simply *oil meal.* Pure linseed meal should contain no screenings. In the United States practically all the linseed oil meal has been made by the old process.

According to Woll,[26] in the manufacture of new-process oil meal the crushed and heated seed is placed in large cylinders or percolators, and naphtha poured over the mass. On draining out at the bottom the naphtha carries with it the dissolved oil. After repeated extractions steam is let into the percolator, and the naphtha remaining is completely driven off as vapor, leaving no odor of naphtha on the residue, which is known as "new-process" linseed oil meal.

[24] Tenn. Bul. 104. [25] U. S. Dept. Agr. Yearbook. [26] Wis. Rpt. 1895.

Recent investigations have shown that in some instances flax seed may contain a compound which, when acted upon by an enzyme in the seeds, yields the poison, prussic acid. This enzyme is destroyed by the heat to which the ground flax seed is ordinarily subjected in both the old and the new process of oil extraction. In view of this and bearing in mind that linseed meal and cake have been fed on vast numbers of farms in this country and abroad with the best of results, we may still consider these feeds among the safest and most beneficial of concentrates. In making gruel or mash from untreated flax seed, it is advisable to use boiling water and keep the mass hot an hour or two, to destroy any prussic-acid-forming enzyme in the seed.

253. Old- and new-process oil meal.—New-process linseed meal carries an average of 3.0 per ct. more crude protein than old-process meal, but it contains only about 2.9 per ct. of oil or fat. The crude protein of the new-process meal is slightly less digestible than that of old-process meal, but owing to its higher total crude protein content, the new-process meal supplies somewhat more digestible crude protein. The new-process meal is slightly less palatable and has less of a beneficial laxative effect than old-process meal. Practically all of the linseed meal is now produced by the old process.

254. Linseed meal as a feed.—There is no more healthful feed for limited use with all farm animals than linseed oil cake or oil meal, with its rich store of crude protein, slightly laxative oil, and its mucilaginous, soothing properties. Its judicious use is soon apparent in the pliable skin, the sleek, oily coat, and the good handling quality of the flesh of animals receiving it. It is therefore very useful as a conditioner for run-down animals. Linseed meal is one of the most popular dairy feeds (**599**), and is excellent for horses. (**487**) It is also one of the best protein-rich supplements for fattening cattle and sheep (**753, 855**), and gives good results with swine when fed in proper combination, but it should not be fed as the only supplement to pigs not on pasture. (**973**) Rich in protein and calcium and fairly high in phosphorus, linseed meal is well suited to young growing animals. Owing to its popularity, linseed meal is often expensive compared with other protein-rich feeds. It is then economy not to use it as the chief source of protein but to feed only enough to produce the desired tonic and regulating effect.

In this country the demand is chiefly for linseed meal instead of the unground cake, probably owing to the fact that it is fed mostly to dairy cows mixed with other concentrates. For sheep, cake ground to nut or pea size is more palatable. European farmers commonly purchase the cake in slab form and grind it in cake mills before feeding. In this form there is no chance for adulteration.

255. Low-grade linseed meal; other flax by-products.—On account of the high reputation held by linseed meal, some concerns are placing on the market products made of mixtures of linseed meal and flax screenings or screenings oil feed (flax screenings from which some of the oil

has been expressed). While pure old-process linseed meal usually contains over 32 per ct. protein, the protein content of these products is as low as 30 per ct. Such feeds may contain 28 per ct. by weight of screenings oil feed. To comply with feeding stuff laws and yet mislead the unwary purchaser, such products are sometimes branded in large letters "oil-process linseed meal" with some such statement below in much smaller letters as "and screenings oil feed." Not infrequently these inferior products have been sold for substantially as high a price as pure linseed meal. Recently considerable Argentine flax seed has been imported into the United States, which at least in some seasons apparently contains less protein than the seed produced in this country. Meal from this seed is often guaranteed to contain but 30 to 31 per ct. crude protein. While such meal is an entirely satisfactory feed, it is of course worth proportionately less than the higher grade meal.

Unscreened flax oil-feed, or "laxo" cake meal, is obtained in extracting the oil from unscreened flax seed. The value is lower than that of linseed meal, depending on the proportion of screenings present.

Flax feed, or flax screenings, is chiefly used in certain mixed feeds. It is sometimes sold as flax flakes, or under the misleading name "linomeal." The composition and value vary widely, depending on the proportion present of low-grade flax seeds and weed seeds and of such trash as stalks, pods, and leaves. It is rarely an economical feed at the prices asked.[27]

Flax plant by-product, sometimes incorrectly called "flax bran," consists of flax pods, broken and immature flax seeds, and the bark and other portions of the stems. It is chiefly used in certain proprietary feeds. Smith of the Massachusetts Station[28] concludes that such material is not worth to the Massachusetts farmer the cost of the freight from the states where it is produced.

256. Soybean.—The soybean, *Glycine hispida,* is one of the most important agricultural plants of northern China and Japan. So great is the production of this seed in Manchuria that before the World War 1,500,000 tons of soybeans were exported in a year, chiefly to Europe. The bean-like seeds of the soybean, which carry from 16 to 21 per ct. of oil, are used for human food and for feeding animals. The oil is used for human food and in the arts, and the resulting *soybean oil meal* is employed as a feed for animals and for fertilizing the land, the same as cottonseed meal. This plant produces the largest yield of seed of any legume suited to temperate climates, but at the present time is grown in this country chiefly for forage. Soybeans are adapted to the same range of climate as corn, early varieties having been developed that ripen seed wherever corn will mature. On account of their resistance to drought they are especially well suited to light, sandy soils. When grown for seed the yield commonly varies from 12 to 40 bushels per acre, equaling corn on poor soil in the Gulf states.

[27] Mass. Buls. 128, 132; Vt. Buls. 104, 133, 144.

[28] Mass. Bul. 136.

The seeds of the soybean are the richest in crude protein of all the various seeds used for feed, besides being rich in oil. Being highly digestible, they contain fully as much digestible crude protein and considerably more digestible fat than linseed meal. Because of the demands for seed, soybeans have not yet been extensively employed in this country for feeding live stock. For dairy cows soybeans are slightly superior to cottonseed meal, but as they cause soft butter they should be fed sparingly. (**600**) For fattening cattle soybeans are only slightly inferior to cottonseed meal. (**754**) Rich in protein and mineral matter, they are well suited to growing animals. (**856**) Owing to their richness in protein, soybeans should always be used in combination with carbonaceous concentrates. The seed should be ground for horses and cattle, but this is unnecessary for sheep and pigs. In the South pigs are often grazed on soybeans when nearly mature, thus saving the harvesting cost. (**989**) For swine feeding, soybean oil meal, from which most of the oil has been expressed, has given much better results than soybeans, probably because soybeans are so rich in oil that they are utilized less efficiently than the soybean oil meal. The merits of this plant for forage are discussed in Chapter XIV. (**358**)

257. Soybean oil meal or cake.—The residue after the oil has been expressed from soybeans carries as much digestible protein as choice cottonseed meal, 13 per ct. more carbohydrates, and somewhat less fat. During recent years a considerable amount has been imported to the Pacific Coast states from the Orient, for feeding poultry and dairy cattle. Thruout the South, some mills have already begun to crush soybeans for the oil. Hence increasing amounts of this feed will be available in this country. Soybean oil meal is greatly esteemed by western dairymen and is an excellent protein-rich feed for swine. (**601, 977**)

258. The peanut and its by-products.—The peanut, or earth nut, *Arachis hypogaea,* called ''pindar'' or ''goober'' in the South, is now of great importance for stock feeding in the southern states. The acreage has increased from 869,887 acres in 1909 to 1,212,000 acres in 1921, the yield of peanuts in the latter year being 816,465,000 lbs. (**362**) The underground seeds, or nuts, are commonly harvested by turning swine into the fields when the seeds are ripe, and allowing them to feed at will. Swine are also turned in to clean up the nuts which are left in the ground when the crop is dug for the peanuts, or which are shattered from the vines in harvesting. While a heavy allowance of peanuts produces soft fat and inferior pork, entirely satisfactory ham and bacon are produced when pigs are fed partially on peanuts. (**979**) On exposure to the air, shelled peanuts soon become rancid. The vines with the nuts attached may be pulled and cured into a nutritious, palatable hay.

Peanut meal or cake, the by-product resulting from the manufacture of oil from the peanut, is a common feed in Europe, where it has given good results with all classes of stock. Meal from hulled peanuts con-

tains 40 to 50 per ct. crude protein, and is thus more valuable than choice cottonseed meal. Considerable peanut meal is now produced in the United States. This varies quite widely in composition, most of it being from unhulled or only partially hulled nuts. The value depends on the protein content and the proportion of hulls present, as shown by the fiber content. Peanut meal is palatable and has given good results in trials in this country with dairy cows, sheep, and pigs. (**606, 856, 979**) Too large a proportion of peanut meal may cause soft pork. Meal from unhulled peanuts should be called *peanut feed,* or *ground whole pressed peanuts,* instead of *peanut meal.* These feeds are also known as *peanut oil meal and peanut oil feed,* respectively.

Peanut hulls, which accumulate in great quantities at the factories, are sometimes ground and used for adulterating feeding stuffs. This material, sometimes wrongly called "peanut bran," is over half fiber and less valuable than common straw.

259. Sunflower seed and oil cake, *Helianthus annuus.*—The sunflower is grown in Russia on a commercial scale, one variety with small seeds producing an oil which serves as a substitute for other vegetable oils. The large seeds of another variety are consumed as a dainty by the people. In tests in North Carolina sunflowers averaged 65 bushels of seed per acre[29] and in Ontario 72.8 bushels per acre,[30] the seed weighing 20 lbs. per bushel. Corn produced over twice as much total digestible nutrients in grain alone, and about as much digestible crude protein. As mentioned later, sunflowers are of promise as a silage crop, especially in the western states. (**384**)

Oil cake from sunflower seed has proved a satisfactory feed for all kinds of stock in Europe. Cake from well-hulled seed contains as much crude protein as linseed meal, but has somewhat more fiber. (**603**)

260. Cocoanut meal.—The residue in the manufacture of oil from the cocoanut, *Cocos nucifera,* known as *cocoanut meal,* is lower in crude protein than the oil meals previously discussed, but it contains somewhat more crude protein than wheat bran and much more fat and has a higher feeding value. It is used to some extent by dairymen in the Pacific Coast states and produces butter of good quality and firmness, therefore being well adapted for summer feeding. (**602**) European experience shows that cocoanut meal may be fed with success to horses, sheep, and swine. (**491**) Cocoanut meal is produced both by the "old process," in which the oil is obtained by pressure, as from cotton seed, and also by the "new process," in which the oil is extracted by means of naphtha. The "old process" meal is higher in fat and slightly lower in protein than the "new-process" meal. Cocoanut meal, especially that high in fat, has a tendency to turn rancid in warm weather, unless thoroly dry.

261. Field peas, *Pisum sativum.*—Field peas, including the common Canada peas, succeed best where spring and summer temperatures are

[29]N. C. Bul. 90b.

[30]Ont. Agr. Col. Rpt. 1913.

moderate, as in Canada, the northern states, and in some of the Rocky Mountain valleys. They do not usually yield over 15 to 20 bushels of 60 lbs. per acre and are raised more largely for seed, for human consumption, or for forage (See Chapter XIV) than as a grain for feeding live stock, due to the fact that the seed is usually worth more for these purposes. Field peas contain twice as much protein as the cereals and are relished by dairy cattle and horses. They are often used for sheep and swine. (**856, 975**)

262. Cowpea, *Vigna catjang.*—The cowpea, a bean-like plant from India and China, now holds an important place in southern agriculture because of its large yield of forage. The early varieties grow well as far north as New Jersey and Illinois. The seed pods of the cowpea ripen unevenly, and therefore when the crop is grown for seed it is necessary to pick the pods by hand as they ripen, or else the crop is cut when about three-fourths of the pods are ripe, and before the first pods are shattered or damaged. For this reason the crop is mostly used for hay, silage, and grazing. (**357**) In composition the cowpea seed is similar to the field pea, with only about 4 per ct. fiber. Successful trials are reported in which cowpeas formed a part of the ration for horses, fattening steers, and pigs. (**755, 978**)

263. The common field bean, *Phaseolus vulgaris.*—Many varieties of the common field bean are grown in this country for human food. Beans damaged by wet are used for animal feeding. Shaw and Anderson of the Michigan Station[31] estimate the cull beans of Michigan at about 100,000 bushels annually. Cull beans are often fed to sheep, producing a solid flesh of good quality, and are also used for swine when cooked. (**976**)

264. Miscellaneous legumes.—The *horse bean* is used in England for feeding stock, especially horses. This legume grows fairly well in some parts of Canada, but has never proved a success in the United States, except in the central coast district of California. (**490**)

Velvet beans, Stizolobium spp., as shown later (**361**) are now one of the important crops of the South. Commonly they are grown with corn to support the vines, and most of the ears of corn and the best of the beans are gathered by hand; stock being then turned in to graze the fields. The dry beans in the pods may be fed to stock without grinding, but it is best to soak them or to grind the beans and pods to form what should be termed *velvet bean feed,* tho often called *velvet bean meal.* Velvet beans are an economical feed for dairy cows and fattening cattle, but the dry beans are not satisfactory for swine. (**604, 760, 991**)

Carob beans, or St. John's bread, *Ceratonia siliqua,* are produced by a legume tree grown chiefly in Mediterranean districts. The seeds are imbedded in a thick fleshy pod which forms about 89 per ct. of the fruit and which is rich in sugars.[32] The ground pods and seeds form carob bean meal, which is used chiefly in certain mixed feeds.

[31] Mich. Bul. 243.

[32] Cal. Bul. 309.

A Forty-acre Field of Soybeans in the Corn Belt

The culture of soybeans is increasing rapidly in the United States. This crop not only furnishes excellent protein-rich hay and pasture, but it also produces the largest yield of seed of any legume suited to temperate climates.

Spanish Type of Peanuts

In the South the peanut has become of great importance for stock feeding during recent years. Spanish peanuts, a small-podded variety, are grown more commonly for "hogging-down" than the large-podded types. (From U. S. Department of Agriculture.)

Skim Milk Is an Excellent Feed for Pigs and Calves

Rich in protein of the highest quality and high in calcium and phosphorus, skim milk is a superior feed for young animals. These young pigs are being fed skim milk and a suitable concentrate mixture inside the "creep," where the sows can not enter. (From Wisconsin Station.)

A Portion of the Union Stock Yards at Chicago

The Chicago Union Stock Yards occupy an area of 500 acres, and have 25 miles of streets and 300 miles of railway tracks. The yards would hold at one time 75,000 cattle, 125,000 sheep, 300,000 hogs, and 6,000 horses and mules. Some of the large packing plants may be seen in the background at the right.

CHAPTER XI

MISCELLANEOUS CONCENTRATES—FEEDING STUFFS CONTROL—CONDIMENTAL FOODS

I. Cow's Milk and its By-products

As we have seen (**115**), milk contains a liberal supply of all the nutrients necessary for young animals. Milk and dairy by-products are almost wholly digestible and thus have high feeding value, considering the amount of dry matter they contain. The proteins of milk have a greater efficiency for growth than those of any of the grains. (**118**) Furthermore, whole milk is especially rich in the fat-soluble vitamine. (**104**)

265. Whole milk.—On account of the value of whole cow's milk, it is rarely fed to stock, except to calves for the first 4 to 6 weeks after birth. (**680**) One should not hesitate to employ whole milk when needed in rearing an orphan foal or lamb (**521, 892**), and young stock being prepared for exhibition can be forced ahead rapidly by its judicious use.

Whole milk usually contains from 2 to 3 per ct. of casein, 0.4 to 0.9 per ct. albumin and traces of other proteins. It carries from 4 to 5 per ct. of milk sugar, which is only slightly sweet, is much less soluble than cane sugar, and has about the same feeding value as starch. When milk sours, some of the sugar is changed to lactic acid, which curdles the casein. This fermentation ceases when about 0.8 per ct. of acid has developed, so that in sour milk usually most of the sugar is still unchanged. As is shown later (**552-64**), the percentage of fat varies widely, depending on individuality, breed, and the portion of the milk drawn, the strippings often containing 10 times as much fat as the first-drawn milk.

266. Skim milk.—Because of the protein and ash it carries, skim milk is of high value for building the muscles and bony framework of young animals. Skim milk from centrifugal separators contains about 3.8 per ct. crude protein, 5.2 per ct. nitrogen-free extract, which in sweet milk is practically all milk sugar, and 0.1 to 0.2 per ct. fat. It is thus a highly nitrogenous feed, having a nutritive ratio of 1:1.5, and should hence be supplemented by carbonaceous concentrates. Skim milk is of the greatest use for feeding young animals when it comes sweet and yet warm from the farm separator.

Due to the high quality of its proteins, skim milk is a most excellent feed for young animals. (**115**) Dairymen have found that with care and judgment they can raise just as thrifty calves when whole milk is gradually replaced by skim milk during the first 4 to 5 weeks, only skim milk being given thereafter, as when the supply of expensive whole milk is continued longer. (**678**) For swine of all ages, and especially

for young pigs, skim milk is unsurpassed as a supplement to the carbonaceous grains. The money value of skim milk for swine is discussed fully in a later chapter. (957-60) This dairy by-product is also excellent for foals which do not secure enough milk from their mothers, and for poultry. (521) When other animals are not available to consume all the milk, it may be profitably fed to horses. (607)

Especially in feeding pigs and poultry, it must be borne in mind that skim milk is low in the fat-soluble vitamine, since the greater part is removed in the butter fat. Therefore, unless other feeds in the ration supply plenty of this vitamine, poor results will follow. For example, for young pigs not on pasture, white corn with skim milk is decidedly inferior to yellow corn and skim milk. In fact, white corn with skim milk will even kill young pigs if they get fat-soluble vitamine from no other source. (104, 202, 939, 957-8)

267. Buttermilk.—This by-product differs little from skim milk in composition, and trials have shown that it has substantially the same value for pigs. (962) Some use buttermilk successfully in rearing calves, especially after they are well started in growth, by gradually accustoming the calves to it, and practicing extreme cleanliness. (695) In eastern Prussia and in Holstein-Friesia suckling foals are fed buttermilk.[1] If allowed to ferment in dirty tanks it is a dangerous feed.

Recently, semi-solid buttermilk and dried buttermilk have been placed on the market. These have given very good results in feeding swine and poultry, but are often uneconomical at the prices asked. (962)

268. Whey.—In the manufacture of cheese practically all the casein and most of the fat go into the cheese, leaving in the whey the milk sugar, the albumin, and a large part of the ash. Whey is more watery in composition than skim milk, containing only about 6.6 per ct. dry matter. It contains about 4.8 per ct. milk sugar and 0.3 per ct. fat, with only 0.8 per ct. protein, the nutritive ratio being 1:6.8, much wider than that of skim milk. However, due to the fact that the protein in whey is of a superior quality, barley and whey alone form an excellent ration for fattening pigs over 150 lbs. in weight.[2] (963) Whey is usually fed to pigs, for which it has about half the value of skim milk. As good results have been secured with whey slightly soured, as with sweet whey, but whey which has been allowed to decompose in filthy vessels is not suitable for stock. Skimmed whey is worth slightly less than unskimmed whey. Whey can be successfully fed to calves only when strictly fresh and when fed with scrupulous care and cleanliness. (695)

269. Spreading disease thru dairy by-products.—Since milk from different farms is mixed at the creamery and cheese factory, the germs of bovine tuberculosis and other diseases may be widely spread from a diseased herd in the skim milk, buttermilk, or whey. The readiness with

[1]Pott, Ernähr. u. Futter., III, 1909, p. 475.

[2]Morrison and Bohstedt, Wis. Buls. 319, p. 70-1; 323, pp. 8-10.

which pigs fed milk from tubercular cows are infected with the disease has been shown in a trial at the Iowa Station.[3]

Since the germs of tuberculosis are killed by pasteurizing the milk at a temperature of 180° F., this simple precaution will remove danger from this source. The pasteurized product also keeps better and is less likely to produce scours. This practice is likewise advantageous to the factories, for the milk cans may be more readily kept in good condition and the quality of the milk delivered at the factory will thereby be improved. Careful farmers should insist that skim milk, buttermilk, and whey be thoroly pasteurized at the factory, a practice required by law in Denmark and in certain states in this country. (957)

II. Packing House By-products

The packing houses now furnish to the feeder great quantities of by-products, including tankage or meat meal, meat scrap, dried blood, and meat-and-bone meal. These are usually extremely rich in protein which is well balanced in composition and highly digestible. Some of them are also rich in lime and phosphoric acid, since they contain more or less bone. When fed in proper combination with other feeds, animals rarely object to these by-products. Owing to the high prices which these concentrated feeds command, the feeder should understand their nature and how they must be fed to secure the best returns.

270. Tankage or meat meal; meat scrap.—At the packing plants the fresh meat scraps, fat trimmings, and scrap bones are thoroly cooked in steel tanks by steam under pressure, which separates the fat. In the larger plants the residue is then pressed to remove the liquid "soup." This is then evaporated down separately to a syrup-like consistency, when it is known as "stick." To the wet, solid meat residue, which has been pressed, are added various proportions of "stick" and sometimes of partly dried blood, and the whole mass is then dried and ground fine, after being passed over powerful magnets to remove nails and other metallic material. The resultant product, sold either as tankage or as meat meal, contains from 40 to 60 per ct. or more of crude protein and from 1 to 10 per ct. of fat. The variation in content of crude protein is due principally to differences in the amount of bone present. Owing to the wide range in crude protein and fat content, these feeds should always be purchased on guarantee of composition. The value will depend chiefly on the percentage of protein, for in case an additional supply of lime and phosphoric acid is needed, it may be furnished cheaply in bone meal or floats. (99) Even tho tankage may be produced in part from the carcasses of diseased animals, there is no danger of it carrying disease to animals fed on it, for it is steam-cooked under pressure and therefore thoroly sterilized.[4]

Meat scraps are a product similar to tankage, but not ground fine. They are used chiefly for poultry.

[3]Iowa Bul. 92.

[4]U. S. Dept. Agr. Bur. Anim. Indus., Cir. 144.

These by-products are generally fed to swine and poultry, ranking next to skim milk and buttermilk as nitrogenous supplements for these animals. (**964-6**) Mixed with other feeds, they may be fed to horses, cattle, or sheep. (**491, 608, 856**) When tankage, or meat meal, contains a large amount of bone it should be termed *meat-and-bone meal.* This product is used chiefly for feeding poultry.

271. Blood meal.—Blood meal, also called blood flour or dried blood, is the richest in protein of all the packing house by-products, usually carrying over 80 per ct. crude protein. As it contains no bone, it is low in ash compared with tankage. Dried blood is particularly useful with young pigs and calves, as a skim milk substitute, or for sickly animals. (**684, 967**) Its usual high price stands in the way of its common use for other animals, but it has been fed with success to horses, dairy cows,[5] and sheep. (**491, 608, 856**)

272. Pork cracklings.—This residue from the manufacture of lard is not commonly found on the market but may be obtained cheaply from local slaughter houses. Pork cracklings contain over 30 per ct. fat and about 7 per ct. less protein than the best grades of tankage. They are fully as valuable as tankage for swine.

273. Fish meal; dried fish.—For many years in Europe the waste parts of fish, as well as entire fishes not used for human food, have been fed in dried form to stock. Only recently, however, have the better grades of dried fish meal, which resemble tankage in composition, been used to any extent for stock feeding in this country. European experience shows that fish meal can be fed successfully to dairy cows[6] and calves[7] and recent trials in this country have proven that it is an excellent protein-rich supplement for swine. (**684, 968**)

274. Bone meal.—As has been discussed in previous chapters (**98-9, 119, 149**), when rations are deficient in lime and phosphoric acid, these mineral nutrients may be supplied by the various forms of bone meal—steamed bone meal, bone flour, or ground bone—or even by ground rock phosphate. The latter is less soluble, tho still available to animals.

III. Sugar Factory By-products

In the manufacture of beet sugar, which constitutes over 75 per ct. of the sugar now manufactured in this country, the sugar beets are first washed and then cut into long V-shaped strips. The juice is extracted from these strips by means of warm water, leaving the by-product known as *wet beet pulp.* The juice is next purified by means of lime and in some cases also by sulfur dioxid, and evaporated under reduced pressure until the sugar crystallizes. The grains of sugar are then separated from the residual *molasses* by centrifugal force.

[5]Lindsey, Mass. Rpt. 1909, Part II, p. 157.
[6]Trans. Highl. and Agr. Soc., 1888, pp. 112-128.
[7]West of Scotland Agr. College, Bul. 84.

275. Wet beet pulp.—The watery pulp, after being pressed until it contains about 10 per ct. of solids, is fed fresh or is ensiled. Care must be taken in feeding fresh pulp, as it spoils rapidly on exposure to the air. Most of the pulp is therefore fed as soured or ensiled pulp. When fed near the factories the pulp is dumped into large, shallow, well-drained pits or trenches, or into huge tank-like silos built chiefly above ground. A more wasteful method is to pile the pulp in large heaps, when the outside layer on rotting will protect the interior from the air. On farms the pulp may be stored in ordinary silos or placed in pits, either with or without alternate layers of beet leaves, the mass, which may extend several feet above ground, being covered with straw and earth to keep out frost. Maercker[8] found that rather more than one-fourth of the total nutrients of the pulp was lost in the fermentations which take place when it is ensiled. Therefore, where possible, the pulp should be dried.

Tho carrying only 1 to 2 per ct. of sugar, wet beet pulp contains considerable of other easily digested carbohydrates, and per pound of dry matter is equal to roots in feeding value. Like roots, this watery material should be fed with dry feeds. Most of the mineral matter is extracted from the beets along with the sugar, and hence the pulp is low in these constituents. When heavy allowances of pulp are fed it is therefore well to see that the animals are supplied with sufficient lime and phosphoric acid. Pulp is also low in crude protein, but fortunately it is commonly fed with legume hay, which is high in both protein and mineral matter.

Steers are annually fattened by thousands and sheep by ten-thousands on wet beet pulp in the vicinity of western beet-sugar factories. Carlyle and Griffith of the Colorado Station[9] found that for fattening steers 1 ton of wet beet pulp replaced 70 lbs. corn plus 575 lbs. alfalfa hay. (**746**) Maynard of the same station[10] reports that 1 ton of wet beet pulp saved 222 lbs. of corn and 208 lbs. alfalfa hay in fattening lambs. (**871**) Beet pulp is also relished by dairy cows, and produces a well-flavored milk, when not fed in too large amounts. (**642**) It may also be fed to idle horses. (**512**)

276. Dried beet pulp.—Owing to the popularity of dried beet pulp as a feed, especially for dairy cows, many factories have been equipped with facilities for thus preserving the pulp. Dried beet pulp is palatable, bulky, and slightly laxative. On account of these properties, experienced dairymen esteem it highly for use as a part of the concentrate mixture for cows on official test which are heavily fed on rich concentrates. Merely as a source of nutrients in feeding cows for economical production, it is worth no more per pound than corn, if added to a ration containing silage or roots. (**585**) Tho used chiefly for dairy cattle, dried beet pulp is also satisfactory for beef cattle and sheep. (**747, 854**)

As dried beet pulp absorbs a great deal of water, when a heavy allowance is fed it is advisable to moisten it with 2 to 3 times its weight of

[8]U. S. Dept. Agr., Bur. Chem., Bul. 52. [9]Colo. Bul. 102. [10]Colo. Bul. 266.

water before feeding.[11] Tho moistened dried beet pulp may be used as a substitute for corn silage, at the usual prices the latter is much more economical for those who can raise most of their own feed.

277. Beet molasses.—The molasses from beet sugar factories is a valuable carbonaceous feed when properly fed, as it contains about 62 per ct. of nitrogen-free extract, which is nearly all sugar. The crude protein of both beet and cane molasses consists largely of compounds having little nutritive value.

When fed in too large amounts, it is very laxative, on account of its high content of alkaline salts and of other purgative substances. In the beet sugar districts the molasses is usually a cheap source of carbohydrates, being valued at three-fourths as much per ton as corn, or more. Due to its sticky nature, the molasses, either undiluted or thinned with water, is usually distributed over hay or straw, while large feeders use machines for mixing the molasses with cut roughage. Animals should gradually become accustomed to the molasses and care must be taken not to feed too large an allowance.

The maximum amounts of molasses advised by various authorities for animals accustomed to the feed are as follows, per 1,000 lbs. live weight: Driving horses, 2.5 lbs., and up to 4 lbs. or even more for draft horses; dairy cows, 2.5 to 3 lbs.; fattening cattle, 4 to 8 lbs.; fattening sheep, 3 to 5; and fattening swine, 5 to 10 lbs. (**483, 748, 854**) Breeding animals should be given smaller allowances than those being fattened, and the amount should be materially reduced 6 weeks before delivery. Beet molasses is extensively used in various mixed feeds, described later. (**281**)

278. Molasses-beet pulp.—Beet molasses is sometimes combined with beet pulp and dried, forming dried molasses-beet pulp. This feed is somewhat more palatable and digestible than the ordinary dried pulp and has equal or slightly higher feeding value. (**586, 854**)

279. Beet tops.—In harvesting sugar beets for sugar, the crown is cut off, as it contains salts which interfere with the recovery of sugar from the juice. When gathered without undue waste, the tops, including the leaves, will weigh about half as much as the marketed beets. Stock may be grazed on the tops (**369**), or the tops, freed from as much soil as possible by shaking, may be ensiled. They are commonly ensiled in pits, often in alternate layers with straw. In the latter case the mass must be packed especially well, and the tops ensiled before they have dried out. When ensiled, the tops are much less purgative than when fresh. The silage is improved by spreading 5 lbs. salt over each ton of tops. The silage is fed with good results, along with hay and other feeds to balance the ration, to fattening cattle and sheep and to dairy cows but it is worth considerably less than good corn silage per ton. (**746**) Not over 30 lbs. daily should be fed to cattle or 3 lbs. daily to sheep.[12]

280. Cane molasses.—Cane molasses, or blackstrap, the by-product of the manufacture of cane sugar, is palatable and much relished by farm

[11]Mass. Rpt. 1910, Part II, p. 24. [12]Jones, U. S. D. A. Farmers' Bul. 1095.

animals. When fed in large amounts it does not have the purgative effect of beet molasses, but is only mildly laxative in its action. Good grades of cane molasses contain 65 per ct. of nitrogen-free extract, which is chiefly sugar. As it contains but 3 per ct. of crude protein, cane molasses should be used, like corn, as a source of carbohydrates, along with protein-rich feeds to balance the ration. When fed in moderate amounts, cane molasses is about equal, pound for pound, to dent corn for fattening steers, horses, dairy cows, and sheep, and has also been fed with success to pigs. (**482, 586, 748, 955**) In addition to the nutrients it supplies, cane molasses is believed to have a favorable effect on the health of animals and serves as a tonic for animals out of condition. By thinning it, and pouring it over or mixing it with roughage, animals may be induced to eat more roughage and waste less than otherwise. This is especially important when feeding unpalatable, low-grade roughage.

In the southern states cane molasses has been extensively used for many years for stock feeding, as it is often one of the most economical feeds available. In the northern states, when it is as cheap as corn or other grains, it may be used with economy as a substitute for corn or other carbohydrate-rich feeds. When it is higher in price than corn, it had best be used in relatively small amount (not over 2 to 3 lbs. per head daily for horses or cattle) as a tonic or to facilitate the disposal of low-grade roughage, and not in place of corn or such feeds.[13] (**482, 748**)

281. Molasses feeds.—Cane and beet molasses are now extensively used in the manufacture of the many *molasses feeds,* which consist of molasses combined with a wide range of products, all the way from high-protein concentrates, such as cottonseed meal, to milling offal, such as screenings, oat hulls, rice hulls, peanut hulls, etc. Many of the early molasses feeds contained a multitude of live weed seeds, were poor in mechanical condition, and did not keep well, on account of excessive moisture. Often entirely unwarranted statements were made in advertising these feeds. The conditions have now improved, and where screenings are present they usually have been finely ground to destroy all weed seeds. Because of the widely differing materials used in these feeds their value varies greatly. If sold at prices which are reasonable compared with the cost of equal amounts of nutriment in the straight concentrates, nothing can be said against the use of the reliable feeds of this class, for they are well liked by stock. (**483**) However, deception is easy in these feeds, because the molasses masks the other ingredients so that inspection does not always show of what the feed consists. Therefore the recommendations given in Articles **288** to **290** should always be followed in purchasing these feeds.

Molassine meal, which has been manufactured for several years in Europe and is sometimes found on the markets in the United States, consists of molasses absorbed by sphagnum moss or peat. Kellner and

[13]Mass. Bul. 118.

Pfeiffer have shown[14] that peat has no nutritive value for farm animals, and the undecomposed moss can likewise have but small worth, tho arctic life subsists on it to some extent. Practically the only nutriment in this feed is in the molasses it contains, and at the prices usually asked, molasses can be purchased much cheaper alone than in molassine meal. Hills[15] found the molasses in a ton of this meal worth only $25, while the feed sold for $39 per ton. Lindsey and Smith[16] of the Massachusetts Station found molassine meal decidedly inferior to corn meal for cows.

282. Sugar.—Tho the nutritive value of sugar is no greater than that of an equal weight of starch, the great fondness for it shown by farm animals makes it helpful in some cases for stimulating the appetite. (**484**) A small allowance is often used in fitting animals for shows.

283. Dried distillers' grains.—In the manufacture of alcohol and distilled liquors from cereals, the corn, rye, etc., after being ground, are treated with a solution of malt to convert the starch into sugar, which is next converted into alcohol by the action of yeast. This is distilled off, leaving a watery residue, known as *distillers' slops,* or *slump.* Formerly the slump was fed to fattening steers at the distillery; now the solid matter is usually strained out and dried in vacuum, forming *dried distillers' grains,* or *distillers' dried grains,* which are sold as such or under various proprietary names. This by-product consists of the portions of the grains not acted upon during the fermentation process, i. e., the crude protein, fiber, fat, and the more insoluble part of the nitrogen-free extract. Distillers' grains from corn contain from 28 to 32 per ct. crude protein and are about equal to gluten feed in feeding value. Dried grains chiefly from rye are of considerably lower value, carrying only about 23 per ct. protein. Not being especially palatable, distillers' grains should be mixed with other concentrates. This rather bulky feed is one of the best high-protein concentrates for dairy cows, from 2 to 4 lbs. per head daily being usually fed. (**605**) Distillers' grains may also be used with good results as part of the ration for fattening steers and sheep. (**758, 856**) A large allowance of the grains is usually not relished by horses, but they may constitute one-fourth the concentrate allowance for these animals. (**491**) On account of their bulkiness they should not be fed in large amounts to pigs. (**981**)

284. Yeast and vinegar grains.—Dried yeast grains and vinegar grains are by-products from the manufacture of yeast and malt vinegar. They are similar to dried brewers' grains in appearance and composition, but are somewhat lower in protein and higher in fiber and hence of lower feeding value.

285. Acorns.—In some portions of the South and in California, *acorns,* the fruit, or nut, of the oak, *Quercus* spp., are of importance in swine feeding, the pigs usually being allowed to forage upon the scattered nuts. Acorns may be used for other stock in limited amounts. Poisoning has been reported where stock ate damaged acorns or too large amounts.

[14] Ernähr. landw. Nutziere, 1907, p. 369. [15] Vt. Bul. 171. [16] Mass. Bul. 158.

286. Miscellaneous by-products.—*Cocoa shells,* the by-product of the manufacture of cocoa and chocolate, consist of the hard outside coating of the cocoa bean. These shells, which are dark brown and brittle, are used in a few mixed feeds. Only 4 to 18 per ct. of the crude protein in this material is digestible. Lindsey and Smith of the Massachusetts Station[17] consider cocoa shells worth not more than half as much as corn meal.

Ivory nuts, or vegetable ivory, the nuts of the palm-like *Phytelepas macrocarpa,* are manufactured into buttons and the residue is ground fine to form *ivory nut meal.* This consists chiefly of mannan, one of the less common carbohydrates. Beals and Lindsey at the Massachusetts Station[18] found this material quite digestible but not worth as much as corn meal.

Palmo midds is a by-product of the manufacture of tin plate. In preparing the tin plate for the market the excess of oil on the plate is removed by scouring it with wheat middlings (often containing some ground wheat screenings). This mixture of middlings and oil is sold as *palmo midds.* It was considered slightly superior to wheat middlings in a trial by Skinner and Starr at the Indiana Station.[19]

287. Salvage grain.—Grain damaged by fire, smoke, or water in warehouse fires is known as salvage grain. Its value depends on how much it is damaged and on the amount of screenings present.

288. Proprietary and mixed feeds.—There are now on the market a host of mixed feeds, chiefly sold under proprietary names. Their composition differs widely, some containing only high-grade concentrates like wheat bran, cottonseed meal, malt sprouts, gluten feed, etc. Others contain more or less screenings or light-weight grain, which will in general be of lower value than good-quality grain. Many of these feeds contain such low-grade by-products as oat hulls, ground corn cobs, flax plant by-products, etc., and some consist largely of such material. Altho the percentages of crude protein, fat, and fiber in any given brand are usually kept at the same figure from month to month, the amounts of the separate ingredients in the feed are seldom guaranteed. Thus the feed put out this year under a certain proprietary name may not be the same as that sold next year under the same name and guarantee. For this reason few trials to determine the value of these mixtures have been conducted by the experiment stations.

Many mixed feeds are the result of honest and intelligent efforts to furnish a ready-mixed, "balanced" concentrate mixture for the various classes of farm animals. Such have won good reputations among intelligent feeders. Others are merely attempts to delude the purchaser into paying as much for mixtures of low-grade, trashy by-products as high-class concentrates would cost. All mixed feeds should be purchased not on the strength of a "fancy" name, but on the guarantee of the amounts of crude protein, fat, and fiber present in the mixture.

[17] Mass. Bul. 158. [18] Journ. Agr. Res. 7, 1916, pp. 301-20. [19] Ind. Bul. 219.

By comparing the fiber guarantee with the fiber content of well-known unmixed concentrates, as given in Appendix Table I, one may estimate the extent to which such refuse as oat hulls and ground corn cobs have been added. Such materials, high in fiber, furnish little nutriment, tho they may give bulk to an otherwise heavy mixture. Before buying mixed feeds, the wise feeder will compare the amount of nutrients he can secure for each dollar in these feeds and in grains and the unmixed standard by-products.

IV. Commercial Feeding Stuffs Control

Because it is often impossible for the stockman to tell from the appearance of a commercial feed whether it is of standard quality or has been adulterated, laws have been enacted to protect honest dealers and manufacturers and the users of commercial feeds alike.

289. Regulation of commercial feeds.—Most of the states now have laws which require that each package of concentrated feed bear a label, tag, or statement giving the percentages of crude protein and fat the feed contains. Some states wisely require that the maximum amount of fiber be guaranteed. (This means that the feed must not contain more fiber than the guarantee states.) In others all ingredients in mixed feeds must be stated. From time to time the officials entrusted with feed supervision issue bulletins setting forth the results of examinations, analyses, etc. All stockmen purchasing commercial feeds should secure and consult these bulletins, in order to post themselves concerning the reliability of the various concerns offering feed for sale in their district. They should also support the officials in the enforcement of the feed-control laws, which are vital to their interests, by promptly reporting any infringements which come to their attention.

Users of purchased feeds in large quantity are generally experienced and buy only the better grades of standard feeding stuffs at close prices, or secure such materials as screenings, etc., at low prices, fully understanding their composition and relative value. The small buyer, often feeling the pinch of poverty, too frequently is looking for feed that sells for less than is asked for standard goods, and so is the more easily caught by the low-grade trashy articles often bearing catchy, high-sounding names. Low-grade feeding stuffs, no matter what their names, are almost sure to bring hardship to the animals that are fed on them, and to the owners of such animals as well. Such feeds are really more like roughages than concentrates, and roughage can be produced on most farms far more economically than it can be purchased in bags from the feed dealer. Whenever one is in doubt as to what to buy, he should consult the feed control officials of his state or purchase only the pure unmixed grains, straight milling or factory by-products, or proprietary feeds of high grade that have won a good reputation.

290. A guide in purchasing commercial feeds.—In purchasing unmixed commercial feeding stuffs the guaranteed composition should be ascer-

tained and compared with the average composition given for the same feed in Appendix Table I. If the feed is markedly lower in crude protein or fat, or is noticeably higher in crude fiber than there shown, it should be viewed with suspicion. Care should also be taken that the feed is fresh, free from mold and rancidity, and that it corresponds in appearance with the descriptions given in the preceding chapters. In buying commercial mixed feeds the precautions emphasized earlier in this chapter should be heeded.

V. Condimental Stock Foods; Mineral or Vitamine Mixtures

In spite of the advice of the experiment stations to the contrary, American farmers continue to spend millions of dollars for various proprietary articles called "stock foods," "condition powders," "tonics," etc.

291. Composition of stock foods.—The better class of stock foods have for their basis such substances as linseed meal or wheat middlings, while the cheaper ones contain ground screenings, low-grade milling offal, the ground bark of trees, etc. To this "filling" is added a small percentage of such materials as common salt, charcoal, copperas, fenugreek, gentian, pepper, epsom salts, etc., with or without turmeric, iron oxid, etc., for coloring. The stockman is told that a tablespoonful of the compound with each feed will cause his stock to grow faster, fatten quicker, give richer milk, etc., etc. Yet this amount will supply only an insignificant part of the dose of these drugs which is prescribed for animals by competent veterinarians.

Tests of many stock foods and tonics by the experiment stations in general show clearly that there is no advantage in their use. Farm animals managed with reasonable care have appetites which do not need stimulating. Sick animals or those out of condition should receive specific treatment rather than be given some cure-all. A good manager of live stock has no use for high-priced stock foods or condition powders, and a poor manager will never have fine stock by employing them. The flattering testimonials which the stock-food companies advertise are explained without granting any special virtue to their "food." The stock foods are usually accompanied by directions which advocate liberal feeding and good care for the animals to be fed in order to "secure the benefits from the tonic." Under this guidance the farmer feeds and cares for his stock better than ever before and secures better results, due not to the stock food but to following the directions which accompanied it. Rather than purchase advice with costly condimental foods the wise feeder will secure it in standard agricultural papers and books, or from the experiment stations and the United States Department of Agriculture.

In rare cases some conditioner may be helpful to stimulate the appetite or otherwise improve the general thrift of the animal. A formula

recommended by Doctor Hadley of the Wisconsin Station[20] is: Common salt, 280 lbs.; dried iron sulfate, 16 lbs.; powdered wood charcoal, 12 lbs.; and flowers of sulfur, 8 lbs. These materials should be well mixed or ground together to make a powder. This mixture, which, it will be noted, consists chiefly of common salt, should be kept in suitable boxes so that the animals may have free access to it.

Artificial Carlsbad salt has recently come into vogue among veterinarians, as a conditioner, especially for horses. The formula for this is as follows:[21] Dried sodium sulfate, 40 parts by weight; sodium bicarbonate, 35 parts; common salt, 15 parts; potassium sulfate, 2 parts. The ingredients should be mixed and powdered. For mature horses 1 to 2 heaping tablespoonfuls, and for mature cattle 1.5 to 3 heaping tablespoonfuls should be given 2 or 3 times daily on the feed. The dose for swine or sheep is one-fifth as much as for horses. Half-grown animals should be given half as much as mature animals; younger ones one-eighth to one-fourth the full dose; and sucklings one-sixteenth the full dose.

292. Mineral mixtures; vitamine preparations.—At the present time many proprietary mineral mixtures and mineral tonics are being widely advertised. While some of these are honest efforts to supply the minerals which may be lacking in certain rations (**95-101, 119, 149**), others are of poor quality and are bolstered up by high sounding names and unwarranted advertising claims. In spite of frequent assertions to the contrary by the manufacturers of such preparations, there is no scientific evidence that any such mineral mixture will prevent or cure contagious abortion. This must be clearly distinguished from non-contagious abortion, which may be produced by a deficiency of lime in the feed of pregnant animals. (**98**) Furthermore, there is no evidence that healthy animals are benefited by such substances as Epsom salts, Glauber's salts, sulfur, potash salt, or copperas, which are contained in many proprietary mineral mixtures. Sick animals need a veterinarian or a specific remedy, not a "cure all." Any mineral supplements needed by stock can be supplied cheaply and easily without paying high prices for proprietary mixtures. (**574, 916**)

On account of the great popular interest in vitamines, certain mixed feeds are being extravagantly advertised as being high in vitamines, and likewise certain proprietary mixtures which are said to be rich in vitamines and are claimed to produce marvelous results. From the facts which have been reviewed earlier, it is evident that live stock fed ordinary good rations have no lack of the water-soluble vitamine. Hence there is no need of supplying them with any yeast preparation, so far as is now known. In fact, if stock are fed as recommended in this volume, there should be no lack of any vitamine whatsoever. Before paying his good money for any mineral mixture or vitamine preparation, the wise stockman will secure unprejudiced advice from his experiment station.

[20]Principles of Veterinary Science, p. 217.

[21]Winslow, Veterinary Materia Medica and Therapeutics, p. 113.

CHAPTER XII

INDIAN CORN AND THE SORGHUMS FOR FORAGE

I. Indian Corn

Indian corn, maize, is the imperial agricultural plant of America. This giant annual grass reaches a height of from 7 to 15 feet in 4 or 5 months' growth, producing under favorable conditions from 10 to 20 tons of green forage per acre, containing from 4,000 to 10,000 lbs. of dry matter. When grown in a dense mass but little seed forms, and we have a rank grass which cures into a bright, nutritious, coarse hay. If the plants grow some distance apart, a large yield of grain results, with excellent forage as a secondary product. Were a seedsman to advertise Indian corn by a new name, recounting its actual merits while ingeniously concealing its identity, either his claims would be discredited or he would have an unlimited demand for the seed of this supposed novelty.

In Chapter I the studies on the composition of the growing Indian corn plant are given at length to illustrate and fix in mind the manner in which plants grow and elaborate food for animals. The student should turn to that most helpful presentation and carefully review what it teaches. This done, he is in position to proceed with the further study of the maize plant here set forth. (The importance of corn as a cereal has already been discussed in Chapter IX.)

293. Corn as a forage plant.—The entire fresh green corn plant may be fed as a soiling crop, it may be ensiled, the crop may be cut and cured as fodder corn, or the grain may be removed and the remaining stover used for feed. As is later shown (**296**), ensiling is by far the most satisfactory means of preserving the entire crop as forage.

The term *fodder corn* or *corn fodder* is applied to corn plants, either fresh or dry, which have been grown primarily for forage, and from which the ears, if they carry any, have not been removed. *Shock corn* and *bundle corn* are terms applied to fodder corn which carries much grain, but which is fed without husking. *Corn stover* is the term applied to cured shock corn from which the ears have been removed. Fodder corn or corn fodder, then, is the fresh or cured corn plant which has been grown for forage, with all the ears, if any, originally produced. Stover is cured shock corn minus the ears. Similarly, the terms kafir fodder, milo stover, etc., are employed in speaking of the forages from the various grain sorghums.

Like the corn grain, corn forage is low in crude protein compared with carbohydrates and fat. As shown in Appendix Table III, the nutritive ratio of corn silage is 1:15.1, and that of fodder corn 1:15.7

to 1:17.1, while corn stover has the very wide nutritive ratio of 1:21.0 or over. Hence, these roughages should be supplemented by feeds rich in crude protein. Corn forage is fair in phosphorus and high in lime, compared with corn and the other cereal grains.

294. Thickness of planting.—How thickly to plant corn for forage to secure the highest feeding value, has been studied at several experiment stations. The following table shows the results secured at the Illinois Station[1] where corn was planted on good prairie soil from 3 to 24 inches apart in the row, all rows being 3 feet 8 inches apart:

Results of planting corn kernels various distances apart in rows

Distance between kernels in row	Good ears per acre	Poor ears per acre	Stover per acre	Stover for each lb. of corn	Total digestible nutrients per acre	Net energy per acre
	Bu.	Bu.	Tons	Lbs.	Lbs.	Therms
3 inches	13	46	4.8	3.6	6,218	5,062
6 inches	37	39	3.7	1.9	5,980	5,137
9 inches	55	22	3.1	1.5	5,539	4,854
12 inches	73	16	3.0	1.3	5,593	4,939
15 inches	63	11	2.9	1.4	5,180	4,538
24 inches	49	6	2.5	1.5	4,207	3,644

With the kernels but 3 inches apart in the row there were 46 bushels of "nubbins," or poor ears, and only 13 bushels of sound ears per acre. This thick planting gave the largest returns in total digestible nutrients per acre, but did not quite come up to the 6-inch rate of planting in yield of net energy, which measures the value of the crop for animals being fed for production. (78-80) With this close planting there were 3.6 lbs. of stover for each pound of grain. The largest yield of sound ear corn was secured by planting the kernels 12 inches apart in the row, or about 12,000 kernels per acre, which should produce 10,000 good stalks an acre. From this the returns were 73 bushels of sound and 16 bushels of poor ears per acre, with only 600 lbs. less digestible matter than from planting the kernels 4 times as thickly.

These trials, confirmed by the work of other stations, teach that when the stockman is seeking to produce grain, with stover secondary, he should plant the kernels at such distance apart as will allow each individual plant to produce full-sized ears. No general rule can be given as to the amount of seed to be planted per acre. This varies greatly and is determined by local conditions. One must know accurately the capacity of his land for corn, and seed accordingly. Where the crop is grown for silage for animals being fed for production, such as dairy cows or fattening steers and sheep, the corn may be planted somewhat more thickly than when grown primarily for grain. However, these animals need considerable grain, and therefore the plants should be given enough space to develop good ears. If the silage were to be fed to such animals as beef breeding cows or stocker steers, being merely maintained over

[1]Ill. Bul. 13.

IN STOCK FARMING CORN STOVER IS UTILIZED

Corn stover contains at least one-fourth the feeding value of the corn crop. In well-planned stock farming this important feed is never wasted.

IN GRAIN FARMING CORN STOVER IS LARGELY WASTED

In exclusive grain farming in the corn belt, the ears are picked from the standing stalks, and the stover is then often allowed to waste away in the field.

A Field of Kafir in Texas

Because of their resistance to drought, the grain sorghums and the sweet sorghums are of great importance as forage crops in the semi-arid districts.

Harvesting Kafir for Silage with a Corn Binder

The grain sorghums not only yield grain which closely approaches corn in feeding value, but also silage but little inferior to corn silage. (From U. S. Department of Agriculture.)

winter with no great production, it might be desirable to plant the crop more thickly, so as to secure a greater yield of digestible nutrients per acre. A still more economical method would perhaps be to plant the corn at the rate usual for grain, and then husk out the ear corn for sale or for feeding other classes of stock, and ensile the corn stover for feeding the beef cows or stocker steers. (300)

295. Nutrients in grain and stover.—Even when grown for the grain, a considerable part of the feeding value of the corn crop is in the stover. In trials at 4 northern stations[2] an average yield of 4,415 lbs. of ear corn and 3,838 lbs. of stover was secured per acre. The stover contained 25 per ct. of the digestible crude protein and 37 per ct. of the total digestible nutrients in the crop. The amount of total digestible nutrients it contains measures the value of the stover for merely carrying animals thru the winter. For fattening animals, dairy cows producing heavy yields of milk, and horses at hard work, a more accurate measure of its value is the net energy it supplies. (78-80) Yet, even on this basis the stover furnished 24 per ct. of the net energy of the crop. This shows clearly the loss of animal food which occurs each year when unnumbered acres of corn stover are allowed to decay in the fields.

The ratio of grain to stalk, and hence the distribution of the nutrients, will vary with the variety and with the section of the country. The rank-growing southern corn will have less of the total nutrients in the ear and more in the stalks.

296. Corn silage.—Indian corn is pre-eminently a silage plant. The solid, succulent stems and broad leaves, when cut into short lengths, pack closely and form a solid mass which not only keeps well but furnishes a product that is greatly relished by stock and is consumed with little waste. Altho with enlarging experience the use of other crops for silage is increasing, by far the greater portion of all the forage stored in silos in this country is corn. The use of corn silage has practically revolutionized the feeding of dairy cattle over a large part of the United States (629-31), and is fast becoming almost equally important in the feeding of beef cattle and sheep. (774-80, 866-9) Thru its use the cost of producing milk and meat may be materially lowered all over the corn belt. Not only is corn silage excellent for cattle and sheep, but it may be used in a limited way with horses that are idle or at light work. (510)

The yield of silage per acre varies widely with the soil and season. A 50-bushel crop of corn should make from 8 to 10 tons of silage, depending on the size and leafiness of the stalks. The importance of corn silage on American farms and the methods of feeding it are discussed further in Chapter XVI and in the respective chapters of Part III.

Corn should be cut for silage when the kernels have hardened and glazed, but while most of the leaves are still green. At this stage the

[2]Summarized by Armsby in Penn. Rpt. 1887.

dent varieties will be well dented. Ensiling the crop should not be delayed longer, else the corn will become too mature to make the most palatable silage, and it may mold unless water is added to the cut forage as it is ensiled. On the other hand, it should not be ensiled before the kernels are in the glazing stage, as was usually done some years ago. If ensiled earlier, a sourer silage is produced, and still more important, a great waste of nutrients occurs, for as has been pointed out previously, the corn crop stores much of its highest quality nutrients during the later stages of growth. (23-7)

297. Losses in ensiling and field curing.—Ensiling is decidedly the best method of preserving corn forage, for less nutrients are lost than when the crop is cured as corn fodder, and corn silage also has a higher feeding value than the same amount of dry matter in dry corn fodder. Trials at various experiment stations[3] have shown that even when cured in well-made shocks, so as to reduce the losses to a minimum, corn fodder or stover standing in the field for a few months loses on the average about 20 per ct. of the dry matter it contains, due to weathering and to fermentations which gradually waste the forage. The losses fall chiefly on the most valuable parts—the sugar, protein, and starch—which are less resistant and more soluble than the fiber.

The losses due to weathering can be lessened by making larger shocks. However, Cooke[4] found that even in the dry climate of Colorado heavy losses of dry matter occurred in corn fodder standing in well-made shocks. In the southern states, due to the heavy winter rainfall, it is especially difficult to cure corn fodder or stover, and the losses in feeding value are much higher than in the North.

Losses also occur when corn fodder is ensiled, because of fermentations which take place in the ensiling process. (404) The extent of the losses will vary quite widely, depending on the stage of maturity of the corn when ensiled, the care with which the cut fodder is packed in the silo, the tightness of the silo walls and doors, and the depth of the silo. Immature corn suffers more loss than corn ensiled at the proper stage of maturity. If the silage is not packed well, or if the silo is not built so that the silage will settle well and so that air will be excluded, much greater losses will occur, and parts of the silage will even be entirely spoiled by mold. As the surface losses, due to the decay of silage at the top of the silo before feeding is started, are the same for shallow and deep silos, obviously there will be a much smaller percentage loss of feed in a deep silo.

In trials during 4 years at the Wisconsin Station[5] King found that the average loss of dry matter in silage from well-matured corn, excluding the loss at the surface of the silo, was 9.1 per ct., ranging from 4.9 per ct. to 12.9 per ct. On the other hand, in trials during 2 years by

[3]Woll, Wis. Rpt. 1891; Hills and Cooke, Vt. Rpts. 1892, 1894; Armsby, Penn. Rpt. 1889.

[4]Colo. Bul. 30.

[5]Wis. Bul. 59.

Hills and Cooke at the Vermont Station[6] the loss of dry matter averaged 19 per ct. Considering all the available data[7] we may conclude that in a silo 30 ft. deep or over, the total loss of dry matter should not be over 15 per ct., if reasonable care is taken to pack the silage and to reduce the losses at the surface of the silage after filling. The losses of dry matter are therefore about 5 per ct. lower when the corn crop is ensiled than when it is cured as dry fodder. Experiments have shown that there is an even greater difference in the loss of crude protein which takes place.

298. Corn silage vs. corn fodder.—Practical experience and observation on thousands of farms, as well as the results of the scientific trials reviewed later in this volume, show that an acre of corn has a much higher feeding value when ensiled than when cured and fed as dry fodder. (**630, 780**) We have already seen that the difference in the loss of nutrients which occurs in the two methods of harvesting the crop is not large. Furthermore, corn silage is no more digestible than dry corn fodder. (See Appendix Table II.) To what then is the decidedly higher value of silage due?

The difference in favor of silage is due partly to the fact that stock usually reject the coarse butts of the corn stalks, even when shredded or cut fine, while good silage is consumed with practically no waste. Another important advantage of silage is that it is much more palatable than dry corn fodder. Therefore, silage-fed animals will consume more feed and hence have more nutrients available for milk or meat production, after supplying the maintenance needs of the body. Hence their production will be much more economical. Like other succulent feeds, silage has a beneficial effect on the health of animals, due in part to the fact that it is slightly laxative in its action. Thus it is a valuable aid in keeping stock in thrifty condition. Because of these advantages of silage, the number of silos continues to increase rapidly in the most progressive live stock sections.

299. The variety of corn for silage.—In the North the question arises as to whether to grow for silage the smaller northern varieties of corn, which bear a relatively large proportion of ears, or the tall, late southern kinds which will not mature before frost. Trials have shown that these rank growing varieties will yield a larger amount of digestible nutrients per acre than the smaller ones,[8] but such immature corn makes silage which is sour and contains but little grain. The stockman with plenty of hay, straw, and stover to feed will wish to fill his silo with a richer and more palatable feed than the southern corn yields, and will therefore use northern dent or flint varieties which will reach the desired stage of

[6]Vt. Rpts. 1892, 1894.

[7]Woll, Wis. Rpt. 1891; Armsby, Penn. Rpt. 1889; N. J. Bul. 19; Ragsdale and Turner, Mo. Bul. 179, p. 23.

[8]Maine Rpt. 1893; Penn. Rpt. 1892; N. Y. (Cornell) Bul. 16; Wis. Rpt. 1888; Minn. Bul. 40.

maturity in the average season. To secure a large tonnage, he will plant the crop somewhat more thickly than for grain production, but yet so as to secure a relatively large proportion of grain to roughage. He will thus secure a rich silage which will materially reduce the amount of concentrates required for his stock.

In late seasons it is best to let corn stand till after frost rather than ensile it too green, for satisfactory silage can be secured from frosted corn, and the crop may mature to a considerable extent before a severe frost comes. If the crop is killed by frost, it should be ensiled quickly, for the storm which usually soon follows will wash out much nutriment from the frosted forage, and the wind will also whip off the dried, brittle leaves. If the plants dry out before all the crop can be ensiled, water should be added as the silo is filled, to insure the necessary fermentations that preserve the silage. When corn is ruined by drought, the silo is likewise the best means of saving all possible feeding value in the crop, water of course being added to the forage as it is ensiled.

300. Corn fodder or stover silage.—It has been found that cured corn forage, when cut into the silo, thoroly moistened, and well-packed will undergo fermentation similar to that which occurs with green material and may be preserved in a satisfactory manner.[9] Tho usually less palatable than silage from green corn, this product has considerable silage odor and is readily consumed by stock, with less waste than is dry fodder or stover. This method is now followed by many farmers, especially in the plains region, some even filling their silos three times a year—in the fall with green corn or sorghum, and later with the cured forage. The essential points in the process are to add enough water so the material will pack well and then to tramp it down with especial thoroness; otherwise the mass will spoil. Tho the water may be applied to the cut material in the silo, more even moisture distribution is possible and hence better silage is produced when a stream of water is run into the blower, thereby wetting the cut fodder before it reaches the silo. Eckles found at the Missouri Station[10] that only about one-third of the total amount of water needed will be taken up by the dry fodder as it passes thru the blower. The remainder should be sprinkled over the fodder in the silo as it is filled. Due to the widely varying water content of field-cured corn forage, it is impossible to state definitely the amount of water to be added in such cases. Some recommend adding about an equal weight of water to the forage, others add just enough so that water may be squeezed out of the cut material.

As corn stover silage lacks the corn grain, it is worth decidedly less per ton than normal corn silage. It is better suited for wintering breeding cows or stock cattle than for feeding milk cows or fattening cattle or sheep, which need considerable concentrates. In trials by Rusk at the Illinois Station[11] corn stover silage has been worth about two-thirds as

[9]Del. Rpt. 1903; Vt. Bul. 170. [10]Mo. Cir. 71. [11]Information to the authors.

much per ton as normal corn silage for wintering beef breeding cows. (789) For dairy cows its value was slightly lower, 61 per ct. that of normal corn silage, in a trial by Morrison, Humphrey, and Hulce at the Wisconsin Station.[12] (632) In recent trials corn stover silage has had an even lower value for fattening cattle, compared with normal corn silage. (781)

301. Removing the ears before ensiling.—Years ago it was recommended that, instead of ensiling the entire corn plant, the ears be removed and cured elsewhere, and only the stalks and leaves converted into silage. This grain-free silage would then be fed along with more or less of the grain separately saved. This matter was tested at the Wisconsin Station[13] and at the Vermont Station[14] with adverse results, the normal corn silage proving superior. (632, 781)

302. Dry corn fodder.—Tho not as palatable and valuable as corn silage, corn grown thickly and cured as dry fodder while the leaves are yet green makes a coarse hay of fair feeding value. Such fodder, with bright, nutritious leaves and small palatable ears that are easily masticated, has a value not appreciated by most stockmen. Overlooking the splendid qualities of corn as a forage plant, too many farmers have become accustomed to growing this giant grass for the grain it yields, using the stover as a straw to be fed or wasted as accident determines.

As it is low in protein, corn fodder gives the best results when legume hay forms part of the roughage, such a combination giving excellent results with dairy cows, beef cattle, and sheep. (620-1, 771, 862) Corn fodder is also an economical substitute for timothy hay with idle horses, brood mares, and growing colts. (500) Corn fodder and stover should be placed in large, well-made shocks, to reduce the losses by weathering. Since the stalks stand almost vertical in the shocks, as the leaves wilt there is ample room for the upward passage of air currents, which rapidly dry the interior and check molds and fermentations. When shock corn is pronounced "dry" by the farmer, it usually carries more water and consequently less dry matter than hay, a fact which should not be overlooked when feeding this forage. Care must be taken that corn fodder or stover is well-cured before it is stacked, and especially before it is stored in the mow, for musty, moldy forage is not only unpalatable but even dangerous. In districts of the South where it is exceedingly difficult to cure corn forage, the silo is particularly useful.

303. Shock corn.—Rather than husking corn and feeding the grain and stover separately, sometimes shock corn is fed, the animals doing their own husking. Shock corn is decidedly inferior to corn silage, and gives the best results with animals not being fed for high production, such as cattle being carried thru the winter and idle horses. It is also sometimes used for fattening cattle or sheep, particularly at the beginning of the fattening period. (735, 771)

[12]Wis. Bul. 323, p. 5. [13]Wis. Rpts. 1891. 1892. [14]Vt. Rpts. 1892, 1894.

304. Corn stover.—The forage which remains after removing the ears from shock corn has a higher feeding value than is usually believed. Stover produced in the northern portion of the corn belt is superior in nutriment and palatability to that grown in the South. As soon as thoroly cured, stover should be placed under cover or stacked, rather than left to waste away in the field. When fed with alfalfa or clover hay, good corn stover may often profitably form half the roughage allowance for fattening cattle or sheep. (**771, 862**) For stock cattle and breeding cows it may be utilized to even a larger extent, and it is also satisfactory as part of the roughage for breeding ewes. While corn stover alone will not quite maintain the weight of growing steers during the winter, stover and legume hay with no grain will make fair gains. This cheap feed is also a satisfactory roughage for horses doing but little work. (**502**) Most of the roughage of dairy cows should be more palatable and nutritious in character, but corn stover may often be economically fed in limited amounts even to them. (**622**)

305. Shredding or cutting stover or fodder.—When shock corn is husked by machinery, the stover is usually cut or shredded at the same operation. Corn fodder is also often passed thru a feed cutter before feeding. This finer material is no more digestible than the uncut forage. However, cutting or shredding usually reduces the waste, as it induces the cattle to eat a greater part of the stalks, unless they are coarse and woody. The cut or shredded forage is also easier to handle, and the waste is in better shape for bedding.

306. Pulling fodder.—In the South the tops of the ripening corn stalks are quite commonly cut off just above the ears, leaving the tall butts, each with an unhusked ear at its top. Next, the leaves are stripped from the butts, and these together with the severed tops are cured into a nutritious, palatable fodder, which is extensively employed for feeding horses and other stock. The previous study of the development of the nutrients in the corn plant shows the folly of this practice. During the last stages of its life the corn plant is busiest in gathering crude materials from air and soil and elaborating them into nutritious food. Removing the top and leaves, at once stops all this work of food making. Stubbs of the Louisiana Station[15] found that pulling fodder caused a shrinkage of from 15 to 20 per ct. in the yield of grain. (**23**)

307. Corn for soilage.—Corn ranks high as a soiling crop on account of its palatability, the high yield of nutrients, and the fact that it remains in good condition for feeding for a much longer period than many other crops grown for soilage. On farms lacking summer silage, feeding corn forage in the green state as soilage should become general, for during the late sumer and early fall, pastures are often too scanty to enable animals to do their best. In the case of dairy cows such a shortage of feed will cause a decrease in milk flow, which often can not be recovered by subsequent liberal feeding. (**421, 643**) An acre of ripening corn fed

[15]La. Bul. 22 (Old Series).

in early fall may thus return twice as much profit as if it were held over until winter. For early feeding sweet corn may often be advantageously used.

II. The Sorghums

In the dry-farming districts, from Nebraska to Texas and Arizona, the sorghums, both the saccharine *sorghos* and the non-saccharine *grain sorghums* are of great and increasing importance as forage crops, because they are far more drought resistant than corn and the leaves remain green late in autumn. (**235-41**) In 1921 Texas alone grew 1,950,000 acres of grain sorghum of all varieties for grain and forage in addition to a large acreage of sorghos. The sorghums, chiefly the sorghos, are valuable crops in the southern states for hay, soilage, or silage, and are also grown in the northern states, chiefly for soilage.

According to Piper[16] 3 tons of air-dry fodder may be considered a good and 6 tons a large return from the sorghums, while maximum yields may reach 10 tons of dry fodder or 40 tons of green material. Reed of the Kansas Station[17] states that under Kansas conditions the sorghums will produce one-third to one-half more forage per acre than corn.

308. Sorghum fodder and stover.—Thruout regions of scanty rainfall the sorghums are most commonly grown in drilled rows of sufficient width to allow horse cultivation, by which the moisture is conserved and larger yields obtained. When grown in drills, not too thickly, much seed is produced and the stalks are somewhat coarse. Sorghum forage is more palatable when cut before fully matured, but the seed should be allowed to reach the early dough stage, for if cut earlier the plants are watery and contain little nutriment. The crop is cured in shocks, the same as Indian corn, but in the case of the juicy-stemmed sorghos, which cure with difficulty, the shocks should be small. If left in the field in humid regions for 3 months or longer, sorgho fodder is apt to sour, due to fermentation of the sugar in the stalks. In sections with ample rainfall the seed is often broadcasted, and the fine-stemmed plants cut with a mower and cured in cocks, the same as the meadow grasses. In the South where the rainfall is ample, or on irrigated lands, 2 to 3 cuttings of sorghum may be secured in a season if the crop is cut before it matures; in the dry-farming districts the crop is usually cut but once.

The various types of grain sorghums have been previously described. (**235-40**) Of this group the kafirs give the largest yields of the most valuable forage, for they are leafy and the stems are more succulent than those of milo, feterita, or kaoliang. Kafir fodder and stover compare favorably in composition and feeding value with that from corn. Feterita ranks next to kafir for forage, while milo, kaoliang, and shallu have less foliage and more pithy stems. (**771, 861**) The dwarf types of

[16]Forage Plants, p. 269. [17]Kan. Cir. 28.

the grain sorghums are often harvested with a grain header, and stock grazed on the standing stalks.

The sorghos with their juicy stalks rich in sugar are grown chiefly for forage. Early varieties, such as Amber cane, ripen earlier than kafir or milo and may be grown wherever corn will mature. Zavitz of the Ontario Agricultural College[18] reports an average plot yield of 16.3 tons per acre from 3 varieties of sorgho tested for 15 years. Snyder of the North Platte, Nebraska, Sub-Station[19] regards sorgho as the best forage plant for the more arid sections of the plains district, where alfalfa can not be grown, being fully equal to good prairie hay in feeding value. Early sorghos have proved the best forage crops on dry farms in northwestern Texas and in Arizona, as they evade drought better than late maturing types. Where rainfall is more abundant the later varieties give a larger yield of forage. The palatable leaves, sweet stalks and freedom from dust make sorgho forage a desirable roughage for stock, especially horses. (**499, 771, 861**)

309. The sorghums for grazing, soilage, and silage.—Especially in the southern states, the sorghums, mainly the sorghos, are widely used as summer pasture for horses, cattle, and swine, as they are available at a time when other crops are exhausted or immature. Owing to the danger from prussic acid poisoning, extreme care must be taken in pasturing second growth or stunted sorghum. (**395**) By feeding the green crop as soilage it is the more completely utilized. Tho sorghum may be cut at any time after it reaches a height of 2 to 3 feet, a greater yield of nutrients will be secured when it is allowed to head. The early varieties of sorghos are admirable soiling crops for the northern states. (**421**)

The sorghums formerly had the reputation of producing much sourer silage than corn. Numerous experiments have now shown, however, that when sufficiently matured, both the sorghos and the grain sorghums make excellent silage. Reed reports from 2-year trials at the Kansas Station[20] that silage from kafir or sorgho, ensiled when the seeds were hard, contained less acid than corn silage and was practically equal to corn silage in feeding value for dairy cows. (**633**) He states that the best way to determine when cane or kafir is ready to ensile is to twist the stalk with the hands. When it is so mature that just a very little juice will run out the proper stage has been reached. As with corn, it is preferable to let the crop of cane or kafir stand till after frost rather than ensile it too green. (**299**)

For beef cattle kafir and sorgho silage have also proved to have practically the same value as corn silage in trials covering several years at the Kansas Station, carried on by Cochel[21] and later by McCampbell and Bell.[22] (**782**) Over a 3-year period the sorghums yielded 35 per ct.

[18]Ont. Agr. College, Rpt. 1913. [19]Nebr. Bul. 135.

[20]Kan. Cir. 28; and information to the authors.

[21]Kan. Bul. 198; Kansas Industrialist, Apr. 18, 1914, May 1, 1915.

[22]Rpt. of Progress of Beef Cattle Experiments, Hays, Kansas, Branch Station, 1919-20.

more silage per acre than did corn. Silage from the sorghums is also an excellent feed for sheep, when made from well-matured plants. (870) McCampbell has found that for carrying beef breeding cows thru the winter, silage made from kafir after the heads had been removed for grain, was a much more economical feed than kafir silage with the heads on, or than either dry kafir fodder or stover. (771) An acre of kafir made into silage after the heads had been removed equalled in feeding value 2.2 acres of dry kafir stover.

The bagasse, or waste, of sorghum syrup factories, should not be wasted, but may be satisfactorily ensiled, as well as the leaves removed before running the stalks thru the mill.

CHAPTER XIII

THE SMALLER GRASSES—STRAW—HAY-MAKING

I. The Smaller Grasses.

The great grain-bearing plants—Indian corn, wheat, rye, barley, oats, rice, and the sorghums—are all members of the grass family, tho they are annuals and require careful cultivation. The smaller grasses are nearly all perennials, thriving without cultivation and producing roughage of high grade. In the humid regions Nature everywhere spreads a carpet of soft, green grass that beautifies the landscape and furnishes an abundance of palatable food for animals. Even in the desert the grasses struggle for existence and yield rich nutriment, tho in meager amount. For recuperating the soil and binding it together and for furnishing food to the domestic animals, the smaller grasses are of supreme importance. In summertime in those regions where grasses flourish, the animals of the farm largely feed themselves, and meat, milk, and wool are produced at the minimum cost for labor.

The smaller grasses may be divided into the sod-formers and non-sod-formers. The sod-formers spread by creeping stems below or above ground. This group includes our most valuable pasture and lawn grasses, such as Kentucky bluegrass and Bermuda grass. The non-sod-formers grow in tufts or bunches, and tho they may increase in size by stooling, do not otherwise spread except by seed. Orchard grass is an example of this class. Certain grasses of the group, as timothy, increase to a limited extent by development and division of bulbs at the base of the stems.

310. Nutrients in grasses at different stages.—Few stockmen realize the great differences in composition between young, immature grass and the same grass at the stage of maturity when usually cut for hay. At the time when cut for hay, the smaller grasses are relatively low in protein compared with carbohydrates and fat, and hence hay from the grasses should always be fed with feeds rich in protein. On the other hand, young, immature grass is rich in protein, compared with the other nutrients it contains. At the Kentucky Station[1] Good found that bluegrass, rye, wheat, and oats, when only 5 to 8 inches tall, contained as high a percentage of protein as green alfalfa or clover. This shows that immature grasses, such as are usually gathered by grazing animals, are protein-rich feeds, and it explains the favorable results secured by feeding only corn, a feed very low in protein, to fattening steers on pasture. Tho young grass is richer in protein than more mature grass, a larger

[1]Ky. Rpt. 1911-13, p. 9.

total yield of both protein and dry matter is secured if the grass is not cut until nearly mature. Thus, when grass is cut for hay at the usual stage, more feed is usually secured per acre than if the same field were grazed by stock. The reason why pasture is so economical as a feed for livestock is not that more feed is secured from a given area, but that there is a great saving in labor of harvesting the crop and feeding the stock.

As an example of the relative yields of pasture and hay, data secured by Crozier at the Michigan Station[2] are of interest. He cut growing timothy 8 times from one plat, while on another he cut it and cured it into hay after making full growth. The hay from the frequently-cut grass was about 3 times as rich in crude protein as that from the nearly mature grass, but almost 4 times as much total dry matter and also the greatest total yield of protein was secured when the grass was approaching maturity.

311. Bluegrass.—Kentucky bluegrass, or June grass, easily ranks first for lawn and pasture in the northeastern United States. By its persistence it often drives out other grasses and clovers from the meadows and pastures. The fact that bluegrass is one of the richest of grasses in digestible protein helps explain the fondness for it shown by stock. Differing from most grasses of the humid regions, mature dried bluegrass is quite readily grazed by animals, thus resembling some of the grasses of the western ranges.

With the coming of spring, bluegrass pushes forward so vigorously that early in May the fields bear a thick, nutritious carpet of green. With seed bearing, the plant's energies become exhausted, and bluegrass enters a period of rest which lasts several weeks, and if a mid-summer drought occurs the plants turn brown and appear to be dying. However, they quickly revive with the coming of the fall rains, and each plant is once more busy gathering nourishment for the coming season's seed bearing. The observant stockman soon learns the folly of relying on bluegrass pasture for a steady and uniform feed supply for his cattle thruout the season. Accordingly, he understocks the pasture in spring so that the excess of herbage during May and June may remain to be drawn upon during the mid-summer dormant period, or he fully stocks it and makes up the later shortage by supplying silage or soilage. In a few districts it has been found profitable to graze bluegrass pastures lightly or not at all in summer, and allow the self-cured herbage to stand for winter grazing. Because of its low, carpet-like growth, bluegrass is primarily a pasture, rather than a hay grass.

312. Timothy.—The acreage of timothy in the United States nearly equals that of all other cultivated hay plants combined, including clover and alfalfa. This cool-weather grass is of especial importance in the northeastern states, where it furnishes probably three-fourths of all hay marketed in the cities. The popularity of timothy is due

[2] Mich. Bul. 141.

to the following points: The seed is cheap and generally of good quality. A field of timothy is quickly established and usually holds well. The grass seldom lodges, may be harvested over a longer period than most grasses, and is easily cured into bright, clean hay which is almost free from dust and can be handled with little waste.

For horses timothy hay is the standard roughage, being preferred especially by city buyers. (493) However, mixed clover and timothy hay, or even legume hay alone, if of good quality, may be successfully used in place of timothy. For dairy and beef cattle and for sheep timothy is greatly inferior to hay from the legumes, for timothy is low in protein and relatively low in lime. Moreover, it is not so well-liked by these animals as is clover or alfalfa, and it does not have the beneficial laxative effect of legume hay. Also, the yield of timothy is not large, for it produces but little aftermath. Therefore, on most farms where timothy is now extensively grown, greater use should be made of the legumes, which not only yield more hay, but at the same time increase the fertility of the land. Red or alsike clover should always be sown with timothy, except when the hay is to be grown for sale and the demand is for pure timothy, for the combination furnishes more and superior hay, even for horses. Grown together, the hay of the first season will consist largely of clover. With the close of the second season most of the clover disappears and the decaying clover roots nourish the timothy which remains. Thus a much larger yield of timothy is obtained, and it also tends to be more nutritious, due to the fertilization by the clover roots.[3] Fodder corn and hay from the cereals—oats, wheat, or barley—are economical substitutes for timothy hay in many cases.

313. When to cut timothy.—The most extensive data on the time to cut timothy for hay are those of Waters and Schweitzer at the Missouri Station.[4] During 3 seasons they determined the yield of dry matter in hay from timothy cut at different stages, and also the yield of digestible nutrients, as found by digestion trials with steers, with the results averaged in the table:

Yield of timothy cut at different stages

	Dry matter per acre	Digestible nutrients per acre			
		Crude protein	Carbo-hydrates	Fat	Total dig. matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Coming into blossom	3,411	135	1,676	43	1,908
Full bloom	3,964	147	1,867	44	2,113
Seed formed	4,089	113	1,802	51	2,030
Seed in dough	4,038	98	1,695	54	1,914
Seed ripe	3,747	92	1,576	38	1,754

Cutting the crop when the seed had just formed gave the largest yield of dry matter per acre, closely followed by the cutting made when the seed was in the dough, and this in turn by the cutting made when the plants were in full bloom. In view of the large storage of nutrients

[3] Minn. Bul. 101.

[4] Mo. Research Buls. 19, 20.

which continues in the corn plant until the grain is mature (23), it at first seems surprising that the last cutting of timothy, made when the seeds were ripe but before they had shattered, yielded 342 lbs. less dry matter than the third cutting. This was due to the partial loss of the lower leaves as the plants matured, to leaching by rain, and to the storage of nutrients in the bulbs at the base of the stems. More important than the total yield of dry matter is the content of digestible nutrients. Owing to decreased digestibility of the later cuttings, at full bloom the crop contained noticeably the most digestible crude protein, carbohydrates, and total digestible matter. While the digestible crude protein had decreased 23 per ct. by the time the seed was formed, there was little or no decrease in the other nutrients up to this stage. Later the yield of both digestible crude protein and carbohydrates fell off markedly. The decrease in total digestible nutrients as the crop matured—a condition opposite to that in the corn crop—is explained both by the reasons mentioned above and by the fact that the maturing corn plant is continuously storing nutrients in the highly digestible grain. Hills of the Vermont Station[5] points out that with the smaller grasses the nutrients stored in the seeds are largely lost to the animal, for the seeds are well protected against mastication and digestion by their small size and hard seed coats.

During 2 years Waters determined the preference of stock for the several cuttings, steers, dairy cows, and sheep being allowed free access to feed racks containing each cutting. Yearling steers with no other feed showed a decided preference for the first cutting over the second and for the second over the third, discriminating sharply against the fourth and especially the fifth. They ate all of the first 3 cuttings before they really began on the fourth or fifth. Those fed liberally on grain and silage did not show such marked preferences for the earlier cut hay. Dairy cows getting grain and silage did not discriminate between the first 3 cuttings, but avoided the later ones. Wethers fed all the corn they would eat showed no preference.

Based on yield of digestible nutrients alone, full bloom appears the best time to cut timothy for hay, but other factors must be considered. In the corn belt, the cutting must often be delayed because the cultivation of corn is then imperative. Immature grass is difficult to cure, the weather early in the season is usually more unsettled, and the ground cooler. When the crop is cut before the large storage of nutrients in the bulbs has occurred, the stand of grass will be impaired, according to Waters. The question is thus complex and must be determined from local conditions. In general we may conclude that for dairy cows, young stock, and sheep, timothy should be cut early, since these animals do not relish hay that is woody and lacks aroma, as does most late-cut hay. For horses and fattening cattle late cutting is favored. These animals subsist mostly on concentrates, and the hay they eat serves more

[5] Vt. Bul. 152.

for "filling," as horsemen say. In any case the harvest should not be too long delayed, lest the grass become tough and stringy and the seeds shatter. In trials with early- and late-cut timothy for fattening steers, Sanborn[6] found that late-cut hay gave better returns. The senior author, in an unpublished duplicate experiment conducted many years ago, reached the same conclusion.

314. Red top, *Agrostis alba* or *vulgaris.*—This grass, of several species, is probably suited to a wider range of climatic and soil conditions than any other cultivated grass. A couple of years are required to establish strong plants from seed, but it then forms a close, well-knit, smooth turf, ranking next to bluegrass in this regard. Red top is often indigenous to northern meadows and should be more generally grown. Tracy of the Mississippi Station[7] found no better grass than red top for marshy lands and seepy hillsides. It is especially valuable on damp lands from Canada to the Gulf States and thrives on soil too acid for most other cultivated grasses. At the same time it will withstand considerable drought and endures on poor uplands. Tho not so well liked as bluegrass, red top furnishes good pasture, and yields a fine-stemmed hay, rated somewhat below timothy in feeding value.

315. Orchard grass, *Dactylis glomerata.*—Tho it does well in full sunlight, this grass thrives better than most others in partial shade. It endures hot weather better than timothy and is well suited to the southern border of the timothy belt. As it starts early in the spring it furnishes valuable pasturage, tho stock prefer bluegrass. It grows in tufts, forming an uneven sod, and hence should be sown with other grasses or clovers, both for hay and pasture. Ripening 2 weeks before timothy, it fits in well with red clover. While late-cut orchard grass makes harsh, woody hay, lacking in aroma, that cut in early bloom is equal to the best of the hay grasses, carrying considerably more crude protein than timothy. This grass is usually persistent, deep rooted, withstands summer droughts well, and continues growth late in the autumn, producing much aftermath.

316. Brome grass, *Bromus inermis.*—For the eastern edge of the northern plains region, stretching from South Dakota to Saskatchewan, brome is the most important cultivated grass, flourishing there as do timothy and bluegrass farther east.

This grass furnishes good crops of hay, equal to timothy in feeding value, for 3 or 4 years after seeding, by which time it usually becomes sod bound and should be renovated by harrowing or shallow plowing. Brome is one of the most palatable of pasture grasses and endures heavy grazing. Tho this grass is one of the most drought-resistant of the cultivated grasses, Snyder[8] found brome unsatisfactory as a hay crop on dry farms in western Nebraska and less productive than the native prairie grasses for pasture, except in seasons with heavier rainfall than usual

[6]Rpt. N. H. Board of Agr., 1880.
[7]Miss. Bul. 20.
[8]Neb. Bul. 135.

in that section. Ladd and Shepperd of the North Dakota Station[9] found brome the best grass for permanent pasture, yielding twice as much protein and no more fiber than timothy. During a 5-year test, brome grass yielded an average of 2 tons of hay at the Manitoba and 1.25 tons at the Saskatchewan Station.[10] (496)

317. The millets.—The millets are rapid growing hot-weather annuals of many races and varieties. Of these, the *foxtail millets,* previously described (243), are the type most grown for forage in the United States. In this group are *common millet,* the earliest, most drought-resistant, and, according to Piper,[11] the most widely grown variety; the less drought-resistant *Hungarian millet,* shorter stemmed and with seeds mostly purplish; and *German millet,* late maturing and with nodding heads, which yields more hay, but not of quite such good quality. The foxtail millets are especially valuable as hay crops on dry-farms in the northern plains region. In the more humid regions they are grown chiefly as catch crops, thriving in hot and even dry weather and reaching the harvest period late in August or September.

Millet should be seeded thickly for hay and should be cut as soon as the blossoms appear. Such hay is useful for cattle and sheep feeding, tho usually less palatable and inferior in feeding value to timothy hay or even bright, fine corn or sorghum fodder. (798, 861) Since millet hay is sometimes injurious to horses, it should be fed sparingly. (498) Millet is inferior to Sudan grass in yield and feeding value in most sections where the latter thrives.

Japanese barnyard millet (*Echinochloa frumentacea*), a close relative of the common barnyard grass, has often been advertised as "billion dollar grass." This plant is much coarser than the foxtail millets and under favorable conditions yields large crops of coarse forage. Lindsey of the Massachusetts Station[12] found this millet less satisfactory than corn for soilage because it is more woody and less drought resistant. For hay it is inferior to the foxtail millets. The *broom-corn millets,* previously described (243), are grown chiefly for seed production, as the yield of forage is low and the stems woody. *Pearl millet* (*Pennisetum glaucum*), also called pencillaria or cat-tail millet, is adapted to the same conditions as the sorghums, which have largely displaced it in both the semi-arid regions and the South. As a soiling crop this tall growing grass has value in the southern states, yielding 3 or more cuttings in a season. It should be cut when 3 to 4 feet high, before the stems become hard.

Teosinte (*Euchlaena Mexicana*), a giant millet resembling sorghum, requires a rich, moist soil and is too tropical to have value north of the southern portion of the Gulf States. The culture of this grass is decreasing in the United States, because on moderately fertile soils it yields less than sorghum, and on rich land less than Japanese cane.[13]

[9] N. D. Bul. 47. [10] Canada Expt. Farms, Rpts. 1902-6.
[11] Forage Plants, p. 288. [12] Mass. Bul. 133. [13] Piper, Forage Plants, p. 303.

318. The small grains for forage.—Oats, barley, wheat, rye, and emmer may all be successfully used for the production of hay, soilage, and pasturage. In 1919 over 5,715,000 acres of small grains were cut for hay in this country, nearly two-thirds the acreage devoted to alfalfa, and more than that of red clover grown alone.[14] Over half the area is in the Pacific coast states, wheat and barley being grown in Washington and chiefly barley in California. More than 40 per ct. of all the hay grown in the southeastern coast states, from North Carolina to Louisiana, is from the small grains. When intended for hay, the cereal grasses should be cut while the grains are in the early milk stage, at which time the stems and leaves may be cured into a bright, dust-free hay of good quality. Bearded wheat, barley, and rye should be cut before the awns harden. Cereal crops which have lodged badly because of overrich soil or excessive rainfall may often be advantageously converted into hay. (494)

In the North, fall-sown rye and wheat furnish excellent late fall and early spring pasture and soilage, while spring-sown oats and barley provide green forage in early summer. Barley is the best cereal grass for late summer seeding, since the young plants do not rust so readily as do other cereals. In the southern states fall-sown grains, including winter oats, may be pastured thru the winter, and if not cropped too closely or too late will still yield considerable hay or grain. At the Alabama (Canebrake) Station[15] a fall-seeded barley field yielded over 11 tons of green forage per acre by the following March. In southern Kansas it was found that fall-sown wheat pastured by cows during mild weather in winter gave a grass flavor to winter butter. The bad flavor which green rye imparts to milk may usually be avoided by grazing the cows thereon for but 2 or 3 hours immediately after milking.

A field sown to rye, wheat, oats, or barley for temporary pasture may be changed to a permanent one by sowing clover and grass seed thereon early in spring in the usual manner. The grass and clover plants will then begin growth under shelter of the young grain plants. Stock may be turned into such pastures to graze on the cereal plants regardless of the young grasses and clovers, but should be kept off the field immediately after rain while the ground is soft. The cattle will tramp out some of the tiny grass plants, but will do no permanent harm. The young grass and clover plants will grow rapidly, and as the cereal plants die will spread until they form a dense, permanent sod. Such double seeding gives the earliest possible summer pasture of rye, wheat, barley, or oats, followed by the more permanent one of mixed grasses and clovers.

If ensiled when the kernels are just past the milk stage or slightly earlier, the cereals make silage of fair to good quality. The crop should be run thru a silage cutter and unusual care taken in tramping down the mass to force as much air as possible out of the hollow stems. Hooper of the Kentucky Station[16] found rye silage relished by cows and not injurious to the flavor of the milk if fed several hours before milking. (637)

[14]U. S. Census, 1920. [15]Ala. Bul. 9. [16]Ky. Exten. Cir. 31.

Beef Cattle Fattening on Bluegrass Pasture

In the northeastern United States, Kentucky bluegrass is by far the most important pasture grass.

Cutting a Fine Field of Timothy

On most farms where timothy is now extensively grown, greater use should be made of the legumes. The latter not only yield more hay, and hay of higher feeding value for most stock, but also increase the fertility of the land.

THE CEREALS FURNISH GOOD FALL AND SPRING PASTURE

In some sections the cereals are widely grown as hay and pasture crops. In the North rye is the most commonly used for pasture.

SUDAN GRASS AND SOYBEANS MAKE A GOOD EMERGENCY CROP

Where Sudan grass thrives, it furnishes good yields of hay which is superior to millet. Sudan grass may be grown with soybeans or cowpeas to increase the richness of the hay in protein. (From Wisconsin Station.)

319. Minor northern grasses.—*Canada bluegrass* (*Poa compressa*) will yield fair pasturage or small crops of hay on poor or thin soil where Kentucky bluegrass fails. It withstands close grazing and is considered excellent for fattening cattle. This grass is important in Ontario and New York and is also abundant in Pennsylvania, the Virginias, and Maryland.

Fowl meadow grass (*Poa flava*), a close relative of Kentucky bluegrass, thrives in the northeastern states on wet land subject to overflow where even red top and alsike clover are killed out. Hills of the Vermont Station[17] reports yields on such wet meadows of 1.2 to 2.5 tons per acre of hay which is as well relished as upland hay.

Meadow fescue (*Festuca elatior*), a tufted, long-lived perennial grass, is adapted to practically the same area as timothy, which excels it for hay. Tho it thrives best on rich moist land, the largest acreage is grown in eastern Kansas.[18] It is best as a pasture grass, starting growth early in the season and continuing till late in the fall. As the seed is high-priced, it is usually sown in mixture with other grasses for permanent pastures.

Italian rye grass (*Lolium multiflorum*) and *English rye grass* (*Lolium perenne*) are short-lived, rapid growing perennials. Tho of great importance in Europe they are little grown in this country, except in the humid region of western Washington and Oregon, where they are among the best pasture grasses.

Slender wheat grass (*Agropyron tenerum*), known in Canada as western rye grass, the only native North American grass which has proved valuable under cultivation, is giving satisfaction in the northern plains district.[19]

320. Bermuda grass, *Cynodon dactylon.*—This low growing, creeping grass is to the cotton belt what Kentucky bluegrass and timothy combined are to the northeastern United States. Bermuda grass forms a dense, soil binding sod, which covers the southern fields with a carpet of green from April to October as pleasing to the eye of the stockman as it is to the animals grazing thereon. It serves best when closely grazed, as otherwise it becomes tough and wiry. Because of its aggressiveness, it drives most other grasses out in summer, but lespedeza or white clover will flourish in spots among this grass and improve the pasture. For winter pasture, when Bermuda is dormant, Bermuda sod may be seeded to bur clover, hairy vetch, or Italian rye grass. (**354, 359, 319**) Piper[20] states that good Bermuda pasture will carry 1 cow to the acre and the best mixed Bermuda and lespedeza pasture will graze 2 animals per acre during the summer. The Louisiana Station[21] grazed 30 head of cattle of all ages on 17 acres of Bermuda grass pasture, mixed with other grasses and some lespedeza, with no other feed from March to November. Killebrew[22] states that on the best alluvial soils 1 acre of Bermuda pasture will graze 10 sheep for 8 months. Bermuda pastures are best

[17] Vt. Bul. 137.
[18] Ten Eyck, Kan. Bul. 175.
[19] Piper, Forage Plants, p. 219.
[20] Forage Plants, p. 243.
[21] La. Bul. 72.
[22] La. Bul. 72.

utilized by subdividing them and turning the stock from one lot to the other. Tho primarily a pasture grass, on rich soil Bermuda gives good yields of hay. While 3 to 4 tons of hay per acre have been secured in 2 to 3 cuttings, according to Piper[23] the average yield does not exceed a ton per acre. (**497, 625**) The stout rootstocks when plowed up are readily eaten by hogs, and in the tropics, when the top growth is scanty, are often pulled up and fed to horses.

321. Johnson grass, *Andropogon halepensis.*—In the South this relative of the sorghums is the worst weed of the cotton planter and at the same time the best meadow grass for many sections.[24] Spreading by seed and vigorous creeping rootstocks, it can be eradicated only with great difficulty, and hence it is not as a rule sown on clean fields. On rich soil in the southern states 3 cuttings of good quality hay may be secured, if cut before maturity. Six tons of Johnson-grass hay per acre are reported, tho the annual return usually ranges from 2 to 3 tons. (**497, 626**) As the grass soon becomes sod bound, it should be plowed every 2 or 3 years. While this coarse grass is not well suited for pasture, it may be cut once each month for soilage during the summer season. The rootstocks are readily eaten by stock, especially hogs, fields sometimes being plowed in Texas to furnish winter feed.[25]

322. Sudan grass; Tunis grass.—*Sudan grass* (*Andropogon sorghum,* var.), a close relative of the sorghums, is a tall annual grass introduced into this country by the United States Department of Agriculture in 1909. It closely resembles Johnson grass, but has broader and more numerous leaves and fortunately has no creeping rootstocks, so that it cannot become a pest. Sudan grass grows 5 to 8 feet high in cultivated rows, and 3 to 5 feet when sown broadcast. For so rank a grass the stems are fine, being seldom larger than a lead pencil. The hay is superior to millet and can be fed to all classes of stock without injury, and the plant is also well suited for soilage[26] or silage. In composition it closely resembles timothy and Johnson grass. Thruout the northern states it yields only one cutting, but farther south it may be cut twice or even more. Sudan grass is adapted to the same conditions as the sorghums, and being drought resistant is one of the most valuable forage crops for the western portion of the plains region, from central South Dakota to Texas. According to Vinall,[27] in 1913, with unusually severe drought, yields ranging from 1.25 to 5.0 tons were secured in this section without irrigation. As Sudan grass is a warm-weather grass it does not flourish at high altitudes or in the extreme northern states. In the corn belt and in the east central states where alfalfa, clover, and timothy flourish, its chief value will be as a catch crop in place of millet. Under irrigation in the Southwest yields of 7.8 to 9.8 tons have been secured, which indicates

[23] Forage Plants, p. 242.
[24] Wing, Meadows and Pastures, pp. 355, 401.
[25] Piper, Forage Plants, p. 246.
[26] Piper, Forage Plants, p. 281.
[27] U. S. Dept. Agr., Farmers' Bul. 605.

its value as a forage to feed with alfalfa.[28] Sudan grass should be cut when in full bloom, or even earlier, if more than one cutting is to be made. It furnishes fair pasture, but should be used with caution on account of the danger from prussic acid poisoning, as with the other sorghums. (395) Along the humid Gulf Coast, Sudan grass does not thrive. Since this grass crosses readily with the sorghums and bears seed closely resembling those of Johnson grass, unusual care is necessary to ensure its purity. Mixtures of Sudan grass and either soybeans or cowpeas are often grown for hay.

Tunis grass, another variety of *Andropogon sorghum* which has been recently introduced into this country, is less leafy and vigorous than Sudan grass, which so far has surpassed it in value for all sections.[29]

323. Japanese cane; sugar cane.—Because of its heavy yields, Japanese cane, a slender stemmed variety of the common sugar cane, *Saccharum officinarum,* is one of the cheapest forage crops that can be grown in the Gulf states, and possibly in southern California. In Florida it furnishes good pasture for cattle and hogs from November to March but is killed by grazing after growth starts in the spring.[30] It may be fed in the fall as silage or may be kept for winter by shocking it in the field. The stalks remain juicy, while the leaves dry out. This crop also makes good silage. Yields of 12 to 25 tons green forage per acre are not unusual.[31]

The tops and leaves of common sugar cane, removed on harvesting the cane, also make satisfactory forage for live stock. Dodson and Staples of the Louisiana Station[32] state that cattle ate silage from sugar-cane tops well. They point out the great loss which occurs when this by-product is not utilized by feeding it to stock.

324. Other southern grasses.—*Crab grass* (*Digitaria sanguinalis*), an annual, weedy, volunteer grass, furnishes more forage in the Gulf states than any other grass. Springing up after early crops, it furnishes fair hay or good fall pasture.[33] *Carpet grass* (*Axonopus compressus*), a perennial with creeping rootstocks, probably ranks next to Bermuda as a pasture grass for the southern half of the cotton-belt, being especially useful on damp lowlands.

Para grass (*Panicum barbinode*) is a coarse, tropical grass with stout runners which may reach 15 to 40 feet, taking root at intervals. It produces several cuttings annually, yielding as much as 4 tons of hay per acre at a single cutting.[34] *Guinea grass* (*Panicum maximum*), a perennial with short creeping rootstocks, furnishes 4 to 6 cuttings in the Gulf region. Tracy[35] states that 1 acre of this grass will carry 4 head of cattle thru the season by soilage, or 3 head by grazing. *Rescue grass* (*Bromus unioloides*), a short-lived perennial, is probably the best grass for temporary winter pastures on rich land in the south. On such soil it grows large enough to be cut for hay.[36] *Natal grass* (*Tricholaena*

[28] U. S. Dept. Agr. Farmers' Bul. 1126.
[29] U. S. Dept. Agr. Farmers' Bul. 605.
[30] Fla. Bul. 105.
[31] Tex. Bul. 195.
[32] La. Bul. 143.
[33] Hunt, Forage and Fiber Crops, p. 117.
[34] Piper, Forage Plants, p. 254.
[35] U. S. Dept. Agr. Farmers' Bul. 300.
[36] Piper, Forage Plants, p. 257.

rosea), when once seeded in the Gulf section, volunteers from year to year, coming after early crops and producing good late summer and fall grazing and good hay.[37]

325. Wild and marsh grasses.—Along certain sections of the Atlantic coast are extensive salt marshes, the best of which are cut for hay at low tide, yielding 0.5 to 1 ton per acre. Lindsey[38] of the Massachusetts Station found such hay from 10 to 18 per ct. less valuable than average mixed hay from the cultivated grasses for dairy cows. (**624**) In all humid regions of the country are large fresh water marshes, some of which are covered with the more nutritious true grasses, while in others the rushes and sedges predominate. Such marsh hay as blue joint, *Calamagrostis Canadensis*, cut before maturity, nearly equals timothy in value.

The prairies of the Great Plains and the grazing ranges of the West support numerous native grasses that furnish excellent pasturage and hay equal to timothy when the growth is rank enough to be cut. (**495, 624, 761, 861**) The sedges and rushes of the mountain states are richer in nutrients than those of the eastern states.[39]

326. Mixed grasses.—No matter how valuable, no single variety of grass should be grown in permanent meadows or pastures, but always a mixture of several kinds in combination with the clovers. In the North a combination of red top, timothy, and orchard grass, together with alsike and medium red clover, will yield a larger tonnage of aromatic, palatable hay than is possible from any single variety. The variety and proportion of grasses and clovers to be included in such a mixture will depend on climate and soil, and can not be discussed in this work. In case of doubt as to the mixture to sow, the stockman should consult the experiment station of his state, which understands the local conditions, and should also observe the growth of the different varieties on his own and adjacent farms. It must be remembered that the presence or absence of sufficient plant food—nitrogen, phosphoric acid, potash, and lime—determines and regulates not only the yield of forage, but also, in large degree, the particular species or varieties of grasses and legumes which do or may grow in any given field.

327. The abuse of pasturage.—Stockmen rely too blindly upon pastures for the maintenance of their cattle during half the year. But a few centuries ago the inhabitants of Great Britain trusted to the growth of natural herbage for the support of their stock not only in summer but thruout the entire year. If their animals, foraging for themselves as best they could, survived the winter, all was well; if they died from starvation, it was an "act of God." We have abandoned the crude practices of our ancestors, and now carefully store in barns an abundance of feed for flocks and herds during winter's rigor. We are amazed that our ancestors were so improvident as to gather no winter feed for their cattle. By turning cattle to pasture in spring and letting them forage

[37]Tracy, U. S. D. A. Farmers' Bul. 726. [38]Mass. Bul. 50. [39]Wyo. Bul. 78.

as best they may until winter we show that all the barbaric blood has not yet been eliminated from our veins. If the summer rains are timely and abundant the cattle are well nourished on these pastures; if drought prevails they suffer for food as surely, and often as severely, as did the live stock of England in winter, years ago. To suffering from scant feed there is added the heat of "dog days" and the ever-present annoyance of blood-sucking flies. Our stockmen will never be worthy of their calling, nor their flocks and herds yield their best returns, until ample provision is made against drought-ruined pastures in summer.

The decline in yield of permanent pastures is often attributed to over grazing. This is undoubtedly a most important cause of the depletion of some of the western ranges, but heavy grazing is not necessarily injurious to pastures in humid regions. Carrier and Oakley of the Virginia Station[40] found in a 5-year test that bluegrass pastures heavily grazed were more productive than those lightly grazed, as weeds were prevented from encroaching. Testing the effect of the often-recommended system of alternate grazing of pastures, they found insufficient increase in yield, measured by the gains made by the steers, to justify the extra expense. In America we have not begun to utilize our pastures as is done in Europe, where stock is still grazed on land worth several hundred dollars an acre. By proper fertilization, reseeding with suitable mixtures of grasses and clovers, and keeping down brush and weeds the productivity of pastures may be both greatly and profitably increased.

Because of over-stocking and over-grazing under the system of free and unrestricted grazing, the carrying capacity of many of the western ranges has been seriously reduced. The day of the "all-year-round" open range is now almost past, and in its place has come a system under which, by the use of supplemental feed for periods of summer drought or winter storm, the natural forage is utilized much more wisely than before. With ranges thus handled the enormous losses of cattle and sheep from starvation, which were all too common in the old range days, are prevented. The improvement under a rational system of grazing has been demonstrated on the grazing areas under the control of the United States Forest Service[41] and by the studies of Thornber and Griffith at the Arizona Station.[42] Fencing or otherwise restricting the range, the development of convenient water supplies, the conservation of the range during periods of seed ripening and germination, and the prevention of soil erosion have greatly increased the carrying capacity of such areas. Thornber cites an instance where, 6 years after fencing, a range of over 25 square miles carried nearly twice as many cattle as before fencing. The animals also kept in excellent condition thruout the year, while formerly they lost weight rapidly during the winter and occasionally some died from shortage of feed.

[40]Va. Bul. 204. [41]Barnes, Western Grazing Grounds. [42]Ariz. Bul. 65.

II. Straw and Chaff

As the cereals and other plants mature, the nutrients which have been built up in the green portions of the plants are in large part stored in the ripening seed, thus exhausting the stems and leaves of easily digested nutrients and leaving in them the resistant woody fiber, or cellulose. All straws are therefore much lower in nutritive value than the same plants cut for hay before maturity. The feeding value of each class of straw may differ widely, depending on the stage at which the crop was cut, the care with which it was cured, and the amount of the more nutritious grasses and weeds present.

328. Straw and chaff of the cereals.—Straw is poor in crude protein and fat, and high in woody fiber, or cellulose, a carbohydrate that requires much energy for its digestion and disposal. (**80**) Accordingly, it should be fed but sparingly to animals at hard work, fattening rapidly, or giving a large flow of milk. For animals at light work, fattening slowly, or giving only a little milk some straw can often be advantageously used. Straw is particularly useful in winter with horses that are idle and cattle that are being carried over without materially gaining in weight. Heat is one of the requirements of such animals, and the large amount of energy expended in masticating, digesting, and passing straw thru the body finally appears as heat which helps warm the body. (**501, 502**) The stockman who understands the nature and properties of straw will usually be able to make large use of it. In Canada and Europe pulped roots and meal are often mixed with straw, which is cut or "chaffed," and the moist mass allowed to soften and even to ferment slightly. It is then readily consumed in large quantities by cattle and sheep with satisfactory results. In many parts of Europe horses are fed cut straw mixed with their concentrates. In trials at the Indiana Station, Skinner and King found oat straw as satisfactory as clover hay for satisfying the desire for dry roughage of steers otherwise fed shelled corn, cottonseed meal, and corn silage. When fed with corn silage, oat straw is equal to corn stover for fattening lambs. (**778, 862**)

Oat straw with its soft, pliable stems is the most nutritious, followed by *barley straw. Wheat straw,* being coarse and stiff, is not so readily eaten by cattle, tho spring-wheat straw is of more value than that from winter wheat. *Rye straw,* harsh and woody, is better suited for bedding than for feed. The chaff of wheat and oats contains more crude protein than does straw, and forms a useful roughage when not unduly contaminated with dust, rust, or mold.

329. Straw from the legumes and other plants.—*Straw from the legumes* contains considerably more crude protein and less fiber than that from the cereals and is more digestible. Therefore it has a higher feeding value when cured well and not moldy. In a trial at the Michigan Station[43] *field-bean straw* proved superior to oat straw for fattening

[43]Mumford, Mich. Bul. 136.

lambs. At the Ohio Station[44] it was found that lambs fed corn and linseed meal made better gains on *soybean straw* than on corn stover, tho refusing 41 per ct. of the soybean straw. *Field-pea straw,* with its finer stems and often still carrying some seed, is worth more than the coarser straw from field beans or soybeans.

While not especially desirable, *flax straw* may be fed in the absence of better roughage. The statement that the stringy fiber of flax forms indigestible balls in the stomach of farm animals is unwarranted, since it is digested the same as other fibrous matter. Green colored straw from immature flax plants should be fed with extreme caution, as it may contain large amounts of prussic acid. Ince of the North Dakota Station[45] found the amount of this poison in straw or chaff from ripe flax plants so small that it could not cause trouble if fed in moderate amounts. Straw containing considerable flax seed or weed seeds has increased value. Wilson of the South Dakota Station[46] advises against feeding flax straw to pregnant animals.

Buckwheat straw is of low value and may cause digestive disturbances if fed in large amount.[47] Nelson of the Arkansas Station[48] states that properly cured *rice straw* is excellent for stock.

III. Hay-making

Thruout the temperate regions hay from the grasses and legumes serves as the common roughage for all the larger animals that produce food or perform labor for man. The conversion of green forage into hay must have been the first great step in changing the nomad herdsman into the farmer-stockman. In the United States for the year 1921, about 74,225,000 acres of land produced 96,802,000 tons of hay worth on the farm $1,090,776,000.[49]

330. Nutritive value of dried grass.—To determine the effect upon its feeding value of drying young grass Armsby[50] conducted a trial at the Wisconsin Station and a later test at the Pennsylvania Station. In the Wisconsin experiment the grass was cut when 9 to 10 inches high, and in the Pennsylvania trial short grass was cut with a lawn mower. In each case half the grass was fed fresh to a cow, and the other half later fed to the same cow after being carefully dried in the sun on canvas in the first trial, and in the second, over a steam boiler. There was no difference in the amount either of milk or butter fat produced on the dried and the fresh grass, showing that perfectly dried grass yields as much nutriment as when fed in the fresh condition. In actual hay making, however, more or less of the finer portions of the plant is always lost.

Exposure to the sun reduces the palatability by bleaching and causes a loss of aromatic compounds, dew works injury, and rain carries away

[44]Carmichael, Ohio Bul. 245.
[45]N. D. Bul. 106.
[46]Breeder's Gaz., 59, 1911, p. 19.
[47]Pott. Ernähr. u. Futter., II, p. 329.
[48]Ark. Bul. 98.
[49]U. S. D. A., Mo. Crop Reporter.
[50]Penn. Rept. 1888.

the more soluble portions. (56) Thus, while the dried grass may theoretically equal the fresh forage, in practice it falls short.

Stockhard[51] cured one sample of meadow hay in 3 days and left another in the field for 13 days in alternate wet and dry weather. Analysis showed that the weathered hay had lost 12.5 per ct. of its total dry substance, representing one-fourth of its original nutritive value. Maercker[52] found the loss in meadow hay exposed to prolonged rain to be 18.4 per ct. of the dry substance. Even greater losses occur when legume hay is exposed to rain. According to Wolff[53] 40 per ct. of the dry matter of clover hay may be extracted by cold water. Headden at the Colorado Station[54] analyzed alfalfa hay before and after exposure to 3 rains, aggregating 1.8 inches, with the following results:

Composition of alfalfa hay before and after exposure to rain

	Crude protein Per ct.	Fiber Per ct.	N-free extract Per ct.	Fat Per ct.	Ash Per ct.
Hay not rained on.....	18.7	26.5	38.7	3.9	12.2
Hay damaged by rain.....	11.0	38.8	33.6	3.8	12.7

It will be noted that the damaged hay contained much less crude protein, considerably less nitrogen-free extract, and much more fiber. Of the original nutrients 60 per ct. of the crude protein, 41.0 per ct. of the nitrogen-free extract, and 33.3 per ct. of the fat,—or 31.7 per ct. of the total dry matter was lost. The actual damage was even greater, for the nutrients lost were those most soluble and hence most easily digested.

331. Hay-making.—The widely varying character of grass and legume crops, the dryness and the temperature of the soil of the meadows, the humidity of the atmosphere, and the intensity and continuity of sunlight and heat, are all modifying factors that combine to make the curing of forage crops into hay one of those arts which cannot be very helpfully discussed in books. However, it is highly important to understand the principles underlying hay-making and have in mind the procedures under the leading systems. Each can then adapt his practice to his own conditions.

In curing hay under ideal conditions, three different processes take place which are well summarized by Piper:[55] (1) A reduction in water content to about 15 per ct. (ranging from 7 per ct. to 25 per ct.); (2) fermentations of the hay produced by enzymes, which usually develop a characteristic aroma; (3) more or less bleaching, due to destruction of the green chlorophyll by sunlight, the bleaching being increased by the action of the dew.

The ends sought in making hay are to secure bright green color, good aroma, retention of the leaves and other finer parts (especially in legumes), and freedom from dust and mold.

[51]Wolff, Farm Foods, Eng. ed., p. 155.
[52]Loc. cit.
[53]Farm Foods, Eng. ed., p. 160.
[54]Colo. Bul. 111.
[55]Forage Plants, p. 24.

When it is desired to secure prime hay without regard to expense, it is mown as soon as the dew is off in the morning, allowed to lie in the swath until dry on the surface, then turned, if heavy, by hand or by hay tedder, or raked into loose windrows. Before the dew falls, it is bunched into well-made cocks and, if sufficiently cured so that it will not mold, is allowed to remain until it has passed thru a sweating process. With legume hay it is well to protect the cocks from rain by hay caps. After sweating, it is usually necessary to open the cocks carefully and in large flakes to avoid shattering the leaves. These flakes rapidly give off their moisture, which by this time has spread evenly to all parts, and the hay is soon ready for the barn. Where the hay was green or damp with rain when cocked, it may be necessary to open the cocks the next morning, recocking before nightfall if still not dry enough. By this system the hay is exposed but little to the bleaching action of the sun and dew, and there is no marked loss of aroma, which, tho unweighable, has real value in rendering hay palatable. Before the partly dried plants are piled into cocks, the leaves will have dried out more than the stems. As the leaves and stems remain alive for some time after having been severed by the mower, if the hay is cocked before the leaves are entirely dried out and thereby killed, they will continue to draw water from the stems. This process is especially important with the legumes, which have thick stems that are usually quite succulent, while the leaves dry rapidly and become brittle and shatter badly. Hay cocked in the afternoon entraps much warm air, and the mass remains in a condition favorable to the transpiration, or giving off, of moisture during the night. The heat yielded by the plant while still carrying on its life functions and the warm air entrapped by grass gathered in the afternoon should not be confused with the heat which may develop in partially cured or damp hay thru fermentation, caused by molds and bacteria.

Hay put into the barn when so dry that it will not pack well, is not in first class condition. It should be mowed away with just that amount of moisture which allows it to settle compactly when treaded down. Salt and lime scattered over hay when put into the mow tend to prevent fermentation and check the growth of molds. Salt also renders it more palatable. These materials are not essential, but are helpful, especially when storing partially cured hay during bad weather. Damp hay may be improved by placing it in alternate layers with dry straw. The straw absorbs moisture as well as aroma from the hay, so that cattle the more readily eat both straw and hay. Hay from second-growth grass, or aftermath, is rich in nutrients, but it is made at a time when the ground is often damp and cool, the days short, and the heat of the sun weak. This combination renders the curing of aftermath difficult, and the product is apt to be of less value than first-crop hay. Cured under favorable conditions, aftermath hay is excellent.

New-made hay is laxative and should not be fed to horses, since it

makes soft flesh and may cause colic. Not until the sweating process has been completed in the mow and the mass cooled off can new-crop hay be fed with entire safety.

332. Making hay under favorable conditions.—On farms where large acreages of hay are made, it is often unprofitable to cure the crop in cocks, owing to the labor involved, even tho better hay is thus secured. Under a system often followed the hay is mown in the morning and by frequent tedding and turning is housed before the dew falls at night. When the weather is very dry, even clover and alfalfa, if dry on the surface of the swath, are often raked directly into small windrows by a side-delivery or other rake, without previous tedding. After curing here for a few hours the hay is loaded from the swath by the hay loader, or, in the West, is hauled to the stack with a sweep rake.

Another method is to cut the crop late in the afternoon so that the dew will not materially affect the plants during the night, because they are but little wilted. Even should rain come it will cause far less injury than if the plants were partially cured. The following day, by aid of tedder or rake, the drying is hastened as much as possible, and the hay placed under cover or in the stack before night.

When these methods are followed with the legumes, it is impossible to avoid much loss of the leaves, for when curing in the swath or windrow the leaves become dry and brittle long before the stems are dry enough to allow the hay to be stored. Headden of the Colorado Station[56] found that 40 to 60 per ct. of the weight of the alfalfa plant is in its leaves, which carry four-fifths of the crude protein and over half of the nitrogen-free extract and fat. Three-fourths of the fiber, or woody portion, of alfalfa is in the stems. He further found that in the dry climate of Colorado, with all conditions favorable, for every ton of alfalfa hay taken off the field not less than 350 lbs. of leaves and stems was wasted, and with unfavorable conditions and careless handling there was lost as much as 3,000 lbs. In other words, it is possible for more hay to be lost than garnered.

In dry climates, to avoid undue loss of leaves and yet save the labor involved in cocking hay by hand, especially with alfalfa and clover, the hay is not allowed to cure long in the swath, but is raked into windrows in the afternoon and allowed to remain there over night. The next morning after the dew is off the hay is bunched with a rake and should be ready to haul by afternoon.[57]

333. Aids in curing hay.—Besides hay caps to protect the cocks of curing hay from rain, especially with such crops as cowpeas and peanuts which are thick stemmed and succulent, devices are often used, under unfavorable weather conditions, to allow the air to penetrate the cocks.[58] The simplest is the perch, which is a stake about 6 feet high with cross arms 2 to 3 feet long. This is driven into the ground so that the cross

[56]Colo. Bul. 110. [57]Jardin and Call, Kan. Bul. 197.
[58]Adapted from Piper, Forage Plants, pp. 26-28.

arms do not touch the earth, and the green or partly-cured plants are then piled on the frame so as to make a tall, slender cock. A somewhat more elaborate device, the pyramid, consists of 3 or 4 legs joined at the top and sometimes shaped so they can be driven firmly into the ground. This permits making a larger cock with an air space in the interior. Other frames combine the characteristics of the perch and the pyramid. Often such crops as cowpeas are stacked before thoro curing, rails supported at the ends being used to separate the stack into layers with air spaces between.

In districts with heavy rainfalls during the haying season, as in some sections of the South, the hay is often stacked in the field on cheap two-wheel trucks or on sleds, when dry enough to cock. It is then covered with canvass or muslin covers and allowed to stand until thoroly cured. When dry, the hay is drawn direct to the barn or baler on these trucks or sleds.[59]

334. Brown hay.—Where weather conditions render it impossible to make good hay by the usual methods, the crop may be preserved as "brown hay." The fresh-cut material may be made into cocks at once, each layer being thoroly compacted by tramping. The curing is brought about by the fermentation which takes place in the moist mass. After the cocks have stood for 48 to 60 hours they are opened out for a time to allow the vapor to escape, and the brown hay may then be safely housed. More commonly the crop is somewhat cured in the air and then piled in compact stacks where it remains until fed. The crop must not be too dry when stacked or it can not be packed firmly enough, and the undue amount of air present permits the fermentation to produce sufficient heat to char the mass. If the crop is too green, it will not cure, but be converted into stack silage. Pott[60] recommends stacking when about one-fourth of the water has been lost by curing. At this stage it will not be possible to wring any water from a wisp of the grass stems. The crop should not be stacked when wet with rain or dew.

The product will vary in color from dark brown to nearly black, depending on the extent of the fermentation. The darker the color the lower will be the feeding value. Brown hay of good quality has an aromatic odor and is well liked by stock. However, the losses of nutrients are much greater than in hay cured by the usual methods, being as high as 40 per ct. The process can therefore be recommended only when the weather is unusually unfavorable. In a trial with fattening steers at the Kansas Station[60a] McCampbell found brown hay about equal to good green-colored alfalfa hay, but black hay was of little value.

335. Spontaneous combustion.—When hay carrying too much moisture is put into the mow or stack, the rapid fermentation taking place causes the production of much heat. In a large mow or stack most of this heat is retained in the mass, producing a rapid rise of temperature. Lamb of

[59]U. S. D. A., Farmers' Bul. 956.

[60]Ernähr. u. Futter., I, 1904, p. 211.

[60a]Jour. Agr. Res., 48, 1919, pp. 303-4.

the Iowa Station[61] states that at 120° to 150° F. all bacteria and molds are killed or made inactive. The oxidations continue and the mass becomes hotter and hotter. Finally, the hay begins to char and at a temperature of from 300° to 400° F. spontaneous combustion may occur and the mass burst into flames. This generally happens a month or six weeks after the hay is stored. The only way to avoid such loss is never to store hay in a large mass unless it is thoroly cured. If hay in a mow or stack heats unduly a day or two after storing, and pungent odors, with much vapor and gas, are given off, it should be removed at once and spread out to dry. Removing the hay later may only hasten spontaneous combustion. All that can usually be done then is to compact the hay as much as possible and cover it with other material so as to keep the air out.

336. Measurement and shrinkage of hay.—In estimating the amount of hay in a stack or mow, it is necessary first to compute the volume in cubic feet. Rules, which differ quite widely, are employed in various parts of the country in reckoning the tonnage from the volume in cubic feet. One often used is that after settling for 30 days it takes 512 cubic feet (which makes an 8-foot cube) to make 1 ton. When the hay has been in mow or stack for 5 or 6 months, 422 cubic feet is considered a ton, and for hay a year or more old, 343 cubic feet (which makes a 7-foot cube). Often it will take 580 cubic feet or more to make a ton of hay which has been in the stack only 30 days or less.

The volume of hay in a mow may be readily computed, but it is more difficult to determine the volume of a stack. Several rules for estimating this have been suggested, that worked out by the United States Department of Agriculture probably giving the most accurate results. This is as follows[62]:

The volume of an oblong stack in cubic feet may be found by using the following formula:

$$F \times O \times W \times L = \text{Volume}$$

In this formula F is a fraction which depends on the shape of the stack, O is the "over" (i. e., the distance from the base on one side of the stack, over the stack, and to the base on the other side), W is the width, and L is the length of the stack. The values of F for stacks about three-fourths as high as they are wide are 0.25 for narrow or triangular stacks, 0.28 for medium full stacks, and 0.31 for full and rounded stacks. Where the height and width are about equal, F is 0.28 for narrow stacks, 0.31 for medium full stacks, and 0.34 for full stacks. Where the height is about one and one-fourth times the width, F is 0.31 for narrow stacks, 0.34 for medium full stacks, and 0.37 for full stacks.

Hay stored in the mow will shrink in weight, due to drying out, and also to fermentations taking place during the sweating process, in which nutrients are broken down into carbon dioxid and water. The shrinkage will vary, depending on the water content of the hay when placed in the mow, and may reach 20 per ct. or over. When hay is stacked the shrinkage is greater, since the outside of the stack is exposed to the weather. A stack 12 feet in diameter has about one-third of its contents in the surface foot.

[61]Iowa Circular 36.

[62]U. S. D. A., Off. of Sec., Cur. 67.

CHAPTER XIV

LEGUMINOUS PLANTS FOR FORAGE

The cereal grains and the grasses are all rich in carbohydrates compared with crude protein, and thus serve primarily as sources of energy and fat in nourishing animals. The legumes comprise the great group of food-bearing plants characterized by their high content of crude protein, and therefore serve especially for building the muscles and the other protein tissues of the body. (92-4) Their great value is due not only to this but also to their richness in lime (97-8), which is required in large amounts by growing animals and those which are pregnant or giving milk. (See Appendix Tables I and VI.)

The leguminous roughages are therefore admirable supplements to the cereal grains, and stand in marked contrast to forage from corn, the sorghums, and the smaller grasses, all of which, if cut when nearly mature, furnish forage low in crude protein and only poor to fair in lime. Thru the proper utilization of roughage from the legumes the amount of concentrates needed to provide balanced rations for farm animals may be greatly reduced. Indeed, for many classes of animals merely legume hay and grain from the cereals furnish a most satisfactory combination. When to these vitally important facts we add the great basic one, that the generous and continuous growing of legumes is absolutely essential to the economical maintenance of soil fertility, then, and only then, do we begin to appreciate the importance of this beneficent group of plants in husbandry. In considering the legumes it must be kept in mind that these crops flourish and build up the nitrogen content of the soil only when the proper nodule-forming bacteria are present in the soil. Where these nitrogen-fixing germs are lacking, it is essential that the soil be inoculated by some means.

I. Alfalfa

337. Alfalfa, *Medicago sativa.*—The alfalfa plant is at its best in the great semi-arid plains region covering the western half of the United States, where the alkaline soil is usually rich and deep, with perfect drainage. When amply watered by irrigation and energized by the tropical sun of summer, alfalfa here furnishes from 2 to 5 cuttings each season, yielding a total of from 2 to 5 tons of nutritious hay per acre. In the hot irrigated districts of the Southwest as many as 9 to 12 cuttings have been secured in a single season. Within the humid region, experience is fast locating districts scattered from Louisiana to Maine

where this plant, which requires a deep, well-drained soil, rich in lime, may be profitably grown. Alfalfa thrives under irrigation in hot semi-arid climates, but languishes when high temperature is combined with a humid climate, except where soil conditions are unusually favorable. Marked success is obtained with alfalfa on certain soils in the lower Mississippi valley where the annual rainfall exceeds 50 inches, but in general a rainfall of over 40 inches is unfavorable to the crop.[1] Where soil and climate are suitable, this long-time perennial returns good crops for many years without reseeding.

The acreage of alfalfa in the United States doubled during the decade 1899 to 1909. During the past decade, the acreage has again nearly doubled, increasing from 4,707,146 acres in 1909 to 8,629,111 acres in 1919. The reason for this surprising advance is revealed in the following table, which gives the average yield per acre thruout the United States from alfalfa, clover, timothy, and corn:

Average returns per acre from alfalfa and other crops

	Yield per acre	Digestible crude protein	Total digestible nutrients	Net energy
	Lbs.	Lbs.	Lbs.	Therms
Alfalfa hay	4,372	463	2,250	1,497
Clover hay	2,624	199	1,336	1,015
Timothy hay	2,340	70	1,134	1,007
Corn (ears and stover)	3,574	150	2,251	1,961

The table, computed from the average returns for the whole country, shows that alfalfa produced by far the largest yield of dry matter per acre of all forage crops generally available, even 22 per ct. more than corn, the king of forage plants. More striking still is the fact that alfalfa produced over 2.3 times as much protein as clover and over 3 times as much as corn. It equaled corn in yield of total digestible nutrients (including fat multiplied by 2.25), tho, owing to the high net energy value of the corn grain, the corn plant considerably surpassed alfalfa in yield of net energy.

Even in the eastern states, larger returns are possible from alfalfa than those given above. Voorhees of the New Jersey Station[2] reports a yield of 26.6 tons of green alfalfa forage per acre from 5 cuttings. This contained 11,785 lbs. of dry matter and 2,328 lbs. of crude protein, or as much as is contained in 7.3 tons of wheat bran.

338. Alfalfa for hay.—Alfalfa should be commonly cut for hay when one-fourth to one-third in bloom. At this time, numerous new shoots will usually be found starting at the crowns of the plants. By harvesting the crop at this stage of maturity, a large yield of high-quality hay is secured, which is leafy and palatable, with no undue amount of fiber. Cutting late reduces the next crop and results in hay of lower quality, while cutting too early may weaken the stand. For horses, hay cut

[1] Piper, Forage Plants and their Culture, p. 310.

[2] Forage Crops.

rather late is preferable to that cut earlier, since it is less laxative, or "washy."

Alfalfa hay is richer than red clover hay in crude protein but is a little lower in fat. It furnishes slightly more total digestible nutrients than clover hay, but in respiration trials with cattle has yielded less net energy per 100 lbs., perhaps due to its more laxative effect. Appendix Tables I, II, and III show that early-cut alfalfa hay is higher in crude protein and lower in fiber and more digestible than that from more mature plants. In making alfalfa hay it is especially important to guard against the loss of the leaves, which are the most valuable portion of the crop. (**332**) Widtsoe at the Utah Station[3] shows that while the leaves and flowers of alfalfa cut in early bloom make up only about 43 per ct. of the hay, they contain over two-thirds of all the crude protein and nearly three-fourths of all the fat in the crop.

The relative value of the different cuttings of hay will depend on the climatic conditions. The second and later cuttings, which are usually finer-stemmed and more leafy than the first cutting, are better, except for horses. In a Utah trial[4] there was little difference in the value of the various cuttings. (**610**) In certain sections of the West, wild foxtail, or squirrel tail grass, *Hordeum jubatum,* injures the quality of the first cutting on account of its objectionable beards. As this grass makes palatable hay when cut early, the crop may be harvested then or may be ensiled, which will soften the beards.

339. Feeding alfalfa hay.—Due to its richness both in protein and mineral matter, especially lime, and also because of its palatability to all classes of stock and its beneficial laxative effect, alfalfa hay has no superior in the list of roughages. It is highly esteemed for feeding dairy cows, which need an abundance of protein and lime for milk production, and commonly commands a considerably higher price than clover hay.

The relative feeding value of alfalfa hay and wheat bran is a question which has received much attention and is often discussed by dairymen. A comparison of the digestible nutrients and net-energy value of these feeds will show that the hay contains only about 85 per ct. as much digestible crude protein as bran, and about 3 times as much fiber. (**218**) It is due to this that alfalfa hay furnishes only about 65 per ct. as much net energy as bran. As shown later (**344, 613**), the results of feeding trials in which alfalfa meal (finely ground hay) has been compared with wheat bran for dairy cows vary, probably due to differences in the quality of hay used. Judging from the composition of average quality alfalfa hay and wheat bran, we should not expect such hay to equal wheat bran in feeding value. Where good quality alfalfa hay is fed to dairy cows, considerably less grain is required than where timothy hay is fed.[5] However, owing to the fact that even choice alfalfa hay is a roughage instead of a concentrate, when alfalfa hay is substituted for

[3]Utah Bul. 48. [4]Utah Bul. 126. [5]Ill. Bul. 146; N. J. Bul. 190.

all or most of the grain the yield of milk is considerably reduced.[6] (611-612)

The fattening of cattle and sheep in the western states has been revolutionized by the use of alfalfa hay, due to the large and economical gains secured when this protein-rich roughage is combined with the carbonaceous grains and perhaps silage or wet beet pulp. (766-8, 857-9) The direct comparisons which have been made of alfalfa hay and red clover hay for fattening cattle and sheep have shown that they have about equal value, when other feeds in the ration supply plenty of protein. In a ration otherwise low in protein, alfalfa hay will be superior to clover, due to its higher protein content.

Alfalfa hay is unexcelled for breeding cattle and sheep and also for young stock.[7] Breeding cows can be wintered in good condition without grain on alfalfa hay, preferably with corn silage in addition. (788) For ewes it is also excellent. (884)

Alfalfa hay is exceedingly valuable for brood sows in winter, as it is much more palatable to these animals than clover hay. (1016) Even for fattening pigs a limited amount of alfalfa hay is sometimes economical. (1010)

340. Pasturing alfalfa.—Alfalfa is not primarily a pasture plant, for it grows from buds on the crowns instead of by a lengthening of the lower parts of the stems and blades, as with the grasses. Especially in humid regions grazing is apt to injure the stand. Cattle and sheep on alfalfa pasture are, moreover, subject to bloat. Nevertheless, this crop furnishes such nutritious pasture that it is grazed on many farms even in the eastern states. To avoid serious injury to the stand, fields should never be pastured until they have become well established and animals should be kept off when the ground is frozen, soft, or muddy. Heavy stocking of the pasture is decidedly injurious, especially with horses and sheep, which gnaw the plants to the ground. Except in districts to which alfalfa is especially well adapted it is best to provide a sufficient area of pasture so that the animals will not keep it grazed so closely but what considerable will grow up to be cut for hay once or twice during the season. Some recommend dividing the area to be pastured into three plots, and pasturing alternately, cutting for hay at the usual stages,[8] but this is not necessary if the above precautions are taken. Except in mild climates, alfalfa should be allowed to grow to a height of 6 to 12 inches in the fall for winter protection.

Alfalfa pasture is especially suitable for horses and pigs, which are not subject to bloat. Gramlich of the Nebraska Station[9] found that horses fed hay at noon only and turned on alfalfa pasture at night stood hard farm work as well as others which were dry-fed. For colts and young horses the succulent alfalfa, rich in protein and mineral matter, is especially helpful. (509) This pasture is the foundation of cheap pork production on thousands of farms. (984-5)

[6] N. J. Bul. 204.
[7] Kan. Bul. 114.
[8] Alfalfa Farming in America, p. 337.
[9] Nebr. Exten. Bul. 28.

CUTTING ALFALFA IN A WESTERN IRRIGATED DISTRICT

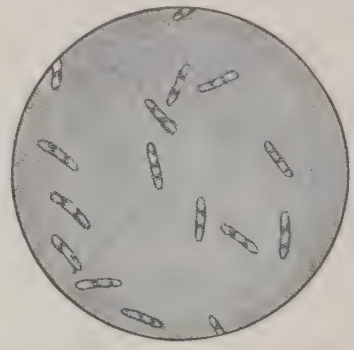
Wherever it thrives the acreage of alfalfa is rapidly increasing, due to its heavy yield of protein-rich hay. (From U. S. Reclamation Service.)

RED CLOVER—A BOON TO FARMERS OF THE NORTHERN STATES

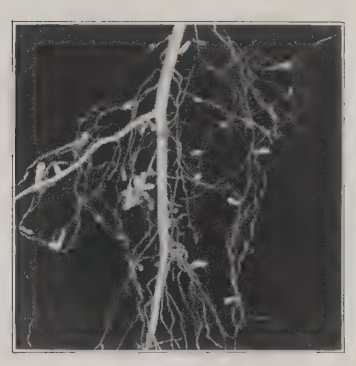
Red clover is the most important legume in the humid parts of the northern two-thirds of the United States. The stock farmer who grows broad acres of clover such as this has a foundation for economical rations.

LEGUMES CAN USE NITROGEN OF AIR ONLY WHEN INOCULATED

When the nitrogen-fixing bacteria or germs are lacking, it is essential that the soil be inoculated to secure maximum crops. At left, are Ito San soybeans on sandy soil which were inoculated with proper bacteria; at right, soybeans which were not inoculated. (All photographs on this page from Wisconsin Station.)



SOYBEAN NODULES (Left) AND SOYBEAN BACTERIA (Right)



ALFALFA NODULES (Left) AND ALFALFA BACTERIA (Right)

The danger to cattle and sheep from bloat varies greatly with climate and other factors. Tho it is always present in some degree, in such sections as the irrigated districts of the Southwest, but trifling loss is experienced. Sheep are more subject to bloat than cattle. The following methods advocated by Coburn[10] and Wing[11] will aid in avoiding bloat, tho no procedure is absolute insurance against loss: For permanent pasture sow with alfalfa, such grasses as bluegrass, brome grass, or others adapted to your conditions. Use upland in preference to lowland for pasture, and have a constant supply of water for the stock. Frosted alfalfa is especially dangerous, but in the late fall after the crop has dried it may be grazed again. Before turning animals on alfalfa for the first time, allow them to fill up on grass pasture, with grain in addition, if they have been accustomed to it. Then in the middle of the forenoon, when they do not care to graze longer, turn them on the alfalfa. Tho some advise allowing the stock to graze only a few minutes the first day and gradually increasing the length of time on the following days, it is probably safer to keep them on the pasture continuously, for they will then never consume undue amounts at one time. Watch the stock closely for the first few days and remove permanently those animals which exhibit symptoms of bloat, for individuals show great differences in their susceptibility to the trouble. The Miller and Lux Co., who graze thousands of cattle on alfalfa in the San Joaquin valley, California,[12] when starting cattle on alfalfa pasture cut part of a field and turn the cattle upon this portion after the alfalfa is half dry. Then after they are well filled they are allowed to eat whatever of the green crop they wish.

341. Alfalfa for soilage.—Alfalfa is one of the most valuable of all soiling crops, owing to the large yields and the fact that under proper management it will furnish rich succulence thruout the entire summer. Considerably more forage may be obtained from a given area as soilage than animals gather by grazing. In a trial with dairy cows by Lyon and Haecker at the Nebraska Station[13] only half as much feed was secured when alfalfa was pastured as when the crop was cut and fed as soilage. Voorhees of the New Jersey Station[14] reports that the first cutting is ready about the last of May or the first of June, with 3 cuttings following at intervals of from 4 to 6 weeks. In certain hot irrigated sections of the West where no satisfactory grass pastures can be provided in summer, dairy cows are often maintained for most of the year mainly on alfalfa, fed as soilage. In the Sacramento valley many herds are fed 30 to 40 lbs. of green alfalfa per head daily with what alfalfa hay they will eat, but no concentrates. The allowance of alfalfa soilage may even be increased to 50 lbs., which amount will furnish nearly 2 lbs. of digestible crude protein.[15] Alfalfa alone makes a very narrow ration, the nutritive ratio being 1:4.0 or less. Undoubtedly larger production

[10]The Book of Alfalfa, pp. 109-119.
[11]Alfalfa Farming in America, pp. 338-344.
[12]Information to the authors.
[13]Nebr. Bul. 69.
[14]Forage Crops.
[15]N. J. Bul. 148.

would be secured were some carbonaceous concentrate added. Whether this would be profitable, however, would depend on the relative price of the feeds. In Europe, where soilage is commonly fed to horses in summer, alfalfa is the most popular crop.[16] Whether to feed alfalfa as soilage rather than graze it will depend on the relative cost of land and labor.

342. Alfalfa silage.—In many instances alfalfa is ensiled with entire success, but often poor, vile-smelling silage is produced. The difficulty seems due to the high protein content of the crop compared with the small amount of sugars, from which the acids necessary to preserve the silage are formed. (**404**) Eckles has recently found in extensive trials at the Missouri Station[17] that entirely satisfactory silage can be made from alfalfa if the alfalfa contains at least 30 per ct. and up to 50 per ct. dry matter. Except when the crop is unusually dry as a result of drought, it is advisable to allow it to lie in the swath for a few hours after mowing, until it is wilted but not dry. In this condition the stems are still green and pliable. Eckles states that alfalfa may be ensiled with good results immediately after having been rained on while being cured for hay. If the alfalfa should get too dry before being ensiled, water should be added. Reed found at the Kansas Station[18] that alfalfa made better silage when mixed with material containing easily fermentable carbohydrates, such as green sorghum, molasses, or corn meal. Owing to the palatability of good alfalfa hay, whenever the crop can be cured in a satisfactory manner there is little reason for ensiling the crop, especially in view of the fact that either corn or the sorghums are reliable silage crops in most sections of the country. (**338**) In the West where foxtail, with its troublesome beards, sometimes greatly injures the quality of the first cutting, it may be profitable to ensile the crop.

343. Types of alfalfa.—Besides the common alfalfa, which is the type chiefly grown in the United States, various other types are of importance in certain sections. *Turkestan alfalfa* is indistinguishable from ordinary alfalfa in growth. It is somewhat hardier than common alfalfa, but usually yields less hay per acre in humid regions. *Arabian and Peruvian alfalfa* are rapid growing, tender strains, which have an unusually long growing season. In the irrigated districts of the Southwest these types are valuable. Several strains of *yellow-flowered, sickle,* or *Siberian alfalfa* (*Medicago falcata*), some of which produce rootstocks, have been introduced into the northern plains district. This type is very hardy but usually produces low yields and hence is not commonly grown. *Variegated alfalfa,* and *sand lucerne* are hybrids between the common and Siberian types, which are exceptionally drought resistant and hardy. The well-known Baltic and Grimm varieties belong to this type.

344. Alfalfa meal and feed.—The manufacture of alfalfa meal (ground alfalfa hay) and various feeds containing more or less of this material has increased rapidly of late. Alfalfa meal varies in fineness from a product nearly as fine as corn meal to a coarsely chopped or shredded

[16] Wing, Alfalfa Farming in America, p. 331. [17] Mo. Bul. 162. [18] Kan. Bul. 217.

material, containing pieces half an inch in length. Compared with hay the meal is easier to transport to distant markets, there is somewhat less waste in feeding it, and for animals having poor teeth, or horses worked long hours, the grinding is undoubtedly beneficial. (507) The bulky meal is also helpful in diluting heavy concentrates, which, if carelessly fed, may cause digestive disturbances. For these reasons alfalfa meal has a legitimate field. However, grinding ever so finely will not transform a roughage into a concentrate. As shown elsewhere (424), with animals having good teeth and ample time to masticate their food, grinding hay does not increase its digestibility. Owing to the great palatability of well-cured alfalfa hay, but little is refused when it is fed long. Unfortunately, it is impossible to determine without chemical or microscopic analysis whether alfalfa meal has been made from nutritious, leafy, early-cut hay or from over-ripe, stemmy material. Hence the meal should be purchased on guarantee of composition, special attention being paid to the fiber content, which in first-class meal should not be higher than in good quality hay, or about 30 per ct.

From 4 trials at the Colorado Station[19] Morton concludes that for fattening lambs the value of ordinary alfalfa hay may be increased 15 to 25 per ct. by grinding, but that with hay of good quality the saving was less. (834) McCampbell of the Kansas Station[20] found that alfalfa meal, fed dry, irritated the nostrils of horses and that they preferred long hay to the meal when wet. He concludes that alfalfa meal is not a desirable or an economical feed for horses when good alfalfa hay is available. (507) In view of the fact that the market price of alfalfa meal is often as high or higher than wheat bran, it is important to note that in most of the trials carried on by the experiment stations substituting good quality alfalfa meal for an equal weight of bran lessened the production of dairy cows. (613) Ordinarily the stockman can produce roughage more economically on his farm than he can purchase it in commercial feeds. In case he desires to mix hay with heavy concentrates the material may readily be cut sufficiently fine in a silage cutter, especially with a cutter provided with an alfalfa screen. Unless good alfalfa meal sells at a lower price than wheat bran its purchase can not be recommended in most instances.

Molasses, either beet or cane, is now mixed with alfalfa meal, the product being sold as "alfalmo" or under other names. The mixture is well-liked by stock, but its economy as a feed must be determined by comparing the composition and price with those of other feeds. Many mixed feeds, discussed in Chapter XI (288), contain more or less alfalfa meal.

II. Red Clover

345. Medium red clover, *Trifolium pratense.*—This legume, commonly known as red clover, is the most important legume in the humid sections

[19]Colo. Bul. 187. [20]Kan. Bul. 186.

of the northern two-thirds of the United States, where, grown in rotation with corn and the cereals, it so helpfully serves for pasture and hay production and for the maintenance of soil fertility. Clover is chiefly seeded in combination with timothy, 19,349,405 acres of mixed clover and timothy being grown for hay in the United States in 1919, compared with only 3,160,415 acres of clover alone. Red clover does best on well-drained soils rich in lime, being intolerant of a water-logged or acid soil. A short-lived perennial, but few plants live over 3 years, and the crop is usually treated as a biennial.

Thruout the clover-growing districts red clover generally yields a heavy first crop of hay, with a second cutting which is usually much lighter and which is often allowed to mature for seed. In the southern states, where it does not thrive during the heat of summer, red clover is sometimes grown as a winter annual, the first crop being cut in the spring and the second in early summer. At the northern limits of its culture but one cutting is produced. The average yield of clover hay per acre, according to the census of 1920, was 1.31 tons, but under favorable conditions much higher returns are secured, the yield in 2 cuttings ranging from 2 to 4 tons or even more per acre.

On all stock farms in the eastern United States there should be a well-planned rotation of crops, such as corn, followed by either wheat, oats, or barley, and this in turn by a legume, preferably red, alsike, or mammoth clover, grown either alone or with the grasses, some of the fields being grazed by the stock.

Under such a rotation, when proper use is made of the farm manure, reinforced by phosphate and potash fertilizers when necessary, the humus and fertility of the soil on the whole farm are maintained or even increased, the weeds are held in check, and the maximum yield of crops is economically produced on all the fields. Because alfalfa fields are usually difficult to establish and should be maintained for many years, the alfalfa plant does not particularly favor a short rotation of crops. In their eagerness to grow alfalfa, ambitious farmers in the East are apt to neglect the clovers, which are so vitally helpful in maintaining fertility of the whole farm in short-time crop rotations. In many cases the growing of red or mammoth clover has been abandoned on account of failure to secure stands. Such "clover sickness" of the soil may be due to certain diseases, but in most cases it means that lime and phosphate, and possibly potash are needed. Farmers who willingly prepare fields thoroly for alfalfa often fail to exercise reasonable care to get good stands of clover.

346. Development of nutrients.—Immature clover, like all young plants, is exceedingly watery. At the Wisconsin Station[21] Woll found but 8.2 per ct. dry matter in green clover cut long before it had reached the proper condition for making hay. Such clover contained more water than skim milk. This explains why clover when cut too early is such

[21]Wis. Rpt. 1889.

unsatisfactory soilage; the animals cannot then consume enough to secure the nourishment they require.

Hunt of the Illinois Station[22] has arranged the result of studies of the medium red clover plant, made by himself and Jordan at the Pennsylvania Station, to show the yield per acre at various stages of growth.

Yield and nutrients in an acre of medium red clover

Stage of growth when cut	Yield of hay per acre	Ash	Crude protein	Carbohydrates Fiber	Carbohydrates N-free extract	Fat
Illinois, Hunt	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Full bloom	3,600	217	400	660	1,052	197
Heads three-fourths dead	3,260	196	379	672	1,024	156
Pennsylvania, Jordan						
Heads in bloom	4,210	260	539	1,033	1,731	116
Some heads dead	4,141	226	469	1,248	1,379	106
Heads all dead	3,915	208	421	1,260	1,378	94

The table shows that when cut at full bloom the clover crop yielded the largest amount of hay per acre, and also contained more ash, crude protein, nitrogen-free extract, and fat. The fiber, or woody matter, which is the least valuable portion of the plant, was the only nutrient which increased after full bloom. The loss of other nutrients after blooming was due to the withering and dropping of the lower leaves and probably to a leaching of soluble nutrients by rains. This shrinkage of nutrients as clover matures is similar to that in the smaller grasses (**313**), and is in marked contrast to the continued storage of nutrients up to full ripening in Indian corn. (**23**)

The table clearly points to full bloom as theoretically the best date for cutting clover hay. Practical experience, however, places the time somewhat later, or when about one-third of the blossom heads have turned brown. This is because at any earlier date the plant is so soft and sappy that only with difficulty can it be cured into good hay. Delaying until all the heads are dead makes haying still easier, but means poor, woody, unpalatable hay.

347. Clover for hay.—Well-cured clover hay, bright and with leaves intact, is a most excellent roughage for all farm stock. Tho dusty clover hay is to be avoided for feeding horses, that of good quality is successfully and economically used with both farm and city horses. (**505**) Mixed clover and timothy hay is preferred by many to clear clover hay for horse feeding since it usually is more free from dust.

No investigations of the experiment stations in animal husbandry have been more helpful than those showing the great value of the legumes, including clover hay, for fattening cattle and sheep. By adding clover hay to the ration, the grain requirement can be materially reduced and the fattening period shortened—both matters of great importance whenever concentrates are high in price. (**764, 857-9**) For the cow, clover hay is unexcelled as a roughage, unless by alfalfa. Not

[22] Ill. Bul. 5.

only is it palatable and much relished, but it is high in protein and lime. Where well-cured clover hay furnishes one-half or more of the roughage, the dairyman is able to cut the allowance of concentrates and materially reduce the cost of the ration. (614) This roughage has the same high place for feeding breeding ewes or beef breeding cows, and especially for young animals. (692, 788, 797-9) Early-cut clover hay ranks next to alfalfa for swine, being especially valuable for breeding stock. (1011) The feeding value of mixed clover and timothy hay of course depends on the proportion of each hay present.

348. Clover for pasture, soilage, and silage.—Clover pasture is helpful and important for all farm animals. For pigs it furnishes about sufficient food for maintenance, so that all the grain fed goes for gain. Clover-pastured pigs are healthy and have good bone and constitution—points of special importance with breeding stock. (986) Tho there is somewhat less danger from bloat with clover than alfalfa, cattle and sheep should not be turned on clover pasture for the first time while hungry or before the dew has risen. As a preventive, dry forage, such as hay or straw, should be placed in feed racks in the pasture. To these cattle and sheep will resort instinctively when bloat threatens.

Clover is particularly valuable for soilage, ranking next to alfalfa among legumes available for that purpose. By cutting clover early, it at once starts growth again if the weather is favorable, and will furnish three or four cuttings annually. Clover may be ensiled if the same precautions are taken as with alfalfa. (342) Ensiling clover is, however, advisable only where the weather prevents its being cured into good hay or where other suitable silage crops can not be grown. (634)

III. Other Clovers and Leguminous Forage Plants

349. Mammoth clover, *Trifolium medium.*—The distinctive characteristics of mammoth clover are its rank growth, coarse stems, and blooming 2 or 3 weeks later than the medium variety. It usually lives 3 years or more and thrives better on poor or sandy soil than does medium red clover. Since it yields but a single cutting during the season, this clover is frequently pastured for several weeks in the early spring. After the stock are removed, the plants shoot up and are soon ready for the mower. Owing to its coarser growth the hay is more difficult to cure and somewhat less palatable than red clover. Wallace[23] recommends that for pasture medium and mammoth clover seed be sown in equal proportions, together with grasses, holding that since mammoth clover blooms later there is more nearly a succession of good forage than is possible with only one variety.

350. Alsike clover, *Trifolium hybridum.*—This variety of clover, once supposed to be a cross between red clover and white clover, has weak stems which fall to the ground unless supported by attendant grasses.

[23]Clover Culture.

Alsike flourishes on land too acid or too wet for other clovers, and is a hardier, longer-lived plant, enduring 4 to 6 years in good soil. As it will grow readily on "clover-sick" soil, it has replaced red clover on many fields during recent years. Well-made alsike hay is fine-stemmed and ranks among the best, being eaten with but little waste. It usually yields but one cutting of hay a year, with some fall pasture in addition.

351. White clover, *Trifolium repens.*—This creeping perennial has the widest range of any of the clovers, thriving in almost any soil from Canada nearly to the Gulf of Mexico, if moisture is ample. In the North it is an important plant in mixed pastures, forming a dense mat of herbage and furnishing feed thruout the growing season. In the South it nearly disappears in summer, but reappears in the fall, furnishing winter pasturage, and thus combines well with Bermuda grass. (**320**) Owing to its low, creeping growth it does not yield hay.

352. Sweet clover.—Biennial white sweet clover, *Melilotus alba,* also known as melilot and Bokhara clover, is widely distributed along roadsides and in waste places over southern Canada and a large part of the United States, thriving best on soils rich in lime. It will grow on soil so poorly drained or so worn and low in humus that alfalfa or red clover will not live. Increasing experience shows that where these more valuable legumes do not thrive, sweet clover, which was once viewed as a weed, is of considerable value. Thousands of acres of depleted, gullied land in Kentucky and Tennessee are being restored to fertility by this legume. In the West it may be grown on hard adobe soils, which it mellows with its deep root system. The plant may be utilized for pasture, hay, and soilage, and has occasionally been ensiled.

At first animals usually refuse sweet clover, for all parts of the plant contain *cumarin,* a bitter compound with a vanilla-like odor. In spring the herbage is less bitter and animals of all classes can generally then be taught to eat it without difficulty. When the clover is cured as hay a large part of the cumarin is volatilized, the hay thus being less bitter than the green plants.

Sweet clover seed should be thickly sown so that the stems will not grow coarse, and the crop should be cut when the first blossoms appear, or even before, since after this stage they rapidly grow woody. Since the stems are quite juicy at this stage of maturity, and are also solid, instead of hollow, like those of red clover, sweet clover is rather difficult to cure into good hay. Unless it is carefully cured the leaves become dry and brittle before the stems are sufficiently cured, and hence shatter badly. The first season one cutting and the second, two cuttings of hay can be secured in the North, and often three in the South. The crop should be cut at least 6 inches from the ground, for the new shoots grow out not from the crown, as in red clover, but from buds on the stems. The hay is satisfactory for horses, cattle, and sheep.[24] (**508, 615, 769, 859**)

[24] U. S. D. A. Farmers' Bul. 1005.

Sweet clover is becoming a popular pasture crop in certain sections of the corn belt, especially when grown in combination with bluegrass. Rusk of the Illinois Station[25] has secured very favorable results with sweet clover as a pasture for beef cattle. It also furnishes good pasture for swine, but is excelled by alfalfa and red clover, where these crops thrive. (987)

An annual variety of sweet clover,[26] recently introduced by Hughes of the Iowa Station, is promising, especially as a soil improver and as an emergency hay crop.

A yellow-flowered biennial sweet clover, *Melilotus officinalis,* two weeks earlier and somewhat smaller in growth than the biennial white sweet clover, has been quite widely introduced in the United States.

353. Crimson clover, *Trifolium incarnatum.*—This annual, adapted to mild climates, is grown chiefly in the Atlantic seaboard states from New Jersey to South Carolina. Here it is treated as a winter annual, being sown in the late summer or early fall, blossoming the following spring, and dying by early summer. Crimson clover has proved vastly helpful to the agriculture of these states, where it is used mainly as green manure and as a winter cover crop. It is widely used for pasture and hay, and to a more limited extent for soilage. This clover is suited to a wide range of soils, succeeding on both sandy and clay land if well drained. Of all the clovers it is said to have the widest adaptability to southern conditions.[27] An especially valuable feature is that the crop may be harvested or turned under as green manure early enough in the spring to permit the raising of other crops the same year.[28] The climate of the humid Pacific coast section is well adapted to crimson-clover culture.

When grown for hay it is important that crimson clover be cut by the time the flowers at the base of the most advanced heads have faded. After this, the minute barbed hairs of the blossom heads and stems become hard and wiry. If hay from over-ripe crimson clover is fed to horses or mules, these hairs sometimes mat together in the digestive tract, forming felt-like masses which may grow to the size of baseballs and finally plug the intestines, causing death. When over-ripe hay must be fed to horses or mules, which are usually the only animals affected, to reduce the danger it should be given with other roughage, preferably with succulent feeds, or else wet thoroly 12 hours before feeding. Cut at the right stage, crimson clover hay is about equal to that from red clover.[29] According to Piper[30] yields of hay from good stands average about 1.25 tons per acre. (615) During a short season in the spring before it matures, crimson clover furnishes valuable pasturage or soilage in advance of grass or other clovers, and in warm sections it may be utilized as late fall or winter pasture.

[25]Information to the authors.
[26]U. S. D. A. Cir. 169.
[27]Ala. Bul. 147.
[28]N. C. Cir. 7.
[29]Del. Bul. 89.
[30]Forage Plants, p. 432.

White Clover Is Valuable in Permanent Pastures

An excellent stand of white clover in permanent blue-grass pasture in the corn belt. This dwarf, creeping clover is an important plant in mixed pastures.

Field Peas Thrive in the Northern States

In the cool climate of the northern states, field peas grow luxuriantly. Especially in combination with oats or barley, they provide good hay, soilage, or pasturage. (From Wisconsin Station.)

LOADING A FINE CROP OF COWPEA HAY

The cowpea, the most important legume in the cotton belt, grows on all types of soil, increasing the fertility of the soil and furnishing rich feed. Cowpea hay is even higher in protein than alfalfa hay.

VELVET BEANS GROWN WITH CORN

Velvet beans are now one of the most important crops of the South. Note the velvet bean vines, which surmount the stalks of corn. (From U. S. Department of Agriculture.)

354. Bur clovers.—The *southern* or *spotted bur clover* (*Medicago arabica*) and *California* or *toothed bur clover* (*M. hispida*) are winter annuals that furnish valuable pasturage in mild regions. The former, which is the hardier, is found chiefly in the southern states, and the latter in California and Texas. They are admirable supplements to Bermuda pasture, furnishing feed when that grass is resting and reseeding unless grazed too closely. (**320**) Even on land where summer cultivated crops are grown, bur clover, if once sown, volunteers in the fall. Cauthen of the Alabama Station[31] states that tho not commonly so used it may be seeded for hay with fall grain.

355. The common field-pea vine.—The common field pea, *Pisum sativum,* var. *arvense,* the use of which as a grain crop has already been discussed (**261**), is grown in Canada and the northern states to some extent for forage. A combination of peas and oats, if cut early, makes nutritious hay, well liked by all classes of stock. Oats and peas make good silage, if not ensiled until the oats are in the late dough stage and the peas have hardened. The combination is frequently sown as a spring soiling crop, especially for dairy cows, or as pasturage, chiefly for swine. In some of the irrigated valleys of the Rocky Mountain region field peas, usually with a small quantity of oats or barley, are sown extensively and grazed when nearly mature by sheep and pigs. (**860, 988**) In the grain which the field pea furnishes and the hay and silage which it is possible to secure from it, the stockman located far north has a fair compensation for the corn crop which he cannot grow.

356. Pea-cannery refuse.—Formerly the bruised pea vines and empty pods from the pea canneries were used only for manure. The value of this rich by-product for stock-feeding has now been abundantly demonstrated, and it is usually preserved in silos or in large stacks, where the decaying exterior preserves the mass within. The silage has a strong odor but is relished by all farm animals, especially dairy cows, fattening cattle, and sheep. (**870**) By spreading cannery waste out thinly on a plat where the grass is short, it may be cured into hay worth, according to Crosby,[32] 20 per ct. more than clover hay, but this involves more labor than placing it in the silo.

357. Cowpea, *Vigna sinensis.*—This hot weather annual is the most important legume in the cotton-belt, furnishing grain for humans and animals (**262**), tho chiefly grown for forage and green manure. Its especial value lies in the fact that it will grow on all types of soil and with but little attention, increasing the fertility of the land and furnishing rich hay, pasturage, soilage, and silage. This vine-like plant does not mature in a definite time, but continues to bear pods and put forth new leaves during a long period. Sown at corn planting or later, early varieties mature the first pods in 70 to 90 days. The crop may be then cut for hay, or the harvesting considerably delayed without loss. Cowpeas yield from 1 to 3 tons of excellent hay per acre, which is equal to red clover or alfalfa in value and is an excellent roughage for horses,

[31]Ala. Bul. 165. [32]U. S. Dept. Agr., Bur. Plant Indus., Cir. 45.

cattle, and sheep. (508, 769, 859) When cowpea hay is fed to dairy cows or fattening steers, the allowance of concentrates may be reduced to one-half the amount needed when a carbonaceous roughage, such as corn stover or hay from the grasses, is fed. (616) Because of the succulent leaves and thick stems the cowpea is difficult to cure. To prevent loss of the leaves the crop should be cured in cocks built with devices which permit air circulation. (333)

For hay it is best to grow cowpeas mixed with sorghum, Sudan grass, Johnson grass, millet, or soybeans, all of which plants support the cowpea vines. From such a mixture a larger yield of hay is secured and the hay is more easily cured.[33] Cowpeas are extensively planted with corn or sorghum, when some cowpea seed is often picked by hand and the remainder of the crop, corn and all, pastured, furnishing economical feed for cattle, sheep, or pigs. (770, 874, 990) The combination crop makes palatable, protein-rich silage that should be more extensively used. Thru the greater utilization of cowpeas and other legumes, the live-stock industry of the South may be enormously increased.

358. Soybean, *Glycine hispida.*—Soybeans are for the most part bushy plants with no tendency to vine, and which, unlike cowpeas, die after the crop of pods has been matured. (256) They thrive in the same climate as corn, maturing sufficiently for hay in northern sections wherever corn may be grown for silage. Soybeans are better adapted to the northern part of the corn belt than cowpeas, which require a longer growing season and are injured by slight frosts. They are also more drought-resistant than cowpeas and hence well suited to light soils, tho they will not thrive on such poor land as do cowpeas. The fondness of rabbits for the plant is a serious drawback in the plains district. The soybean crop should be cut for hay when the pods are well formed but before the leaves begin to turn yellow, for soon after this the stems become woody and the leaves easily drop off. The crop yields from 1 to 3 tons per acre of hay nearly equal to cowpea or alfalfa hay in value. (617) Soybeans alone make rank-smelling silage, but 1 ton of soybeans ensiled with 3 to 4 tons of corn or sorghum makes a satisfactory product. For this purpose the soybeans and corn or sorghum may be mixed as ensiled or they may be grown together. Soybeans alone or soybeans and corn are often grown as a pasture crop for hogs. When designed for pasture the beans should be planted in rows to lessen the loss by tramping, and the hogs should not be turned in until the pods are nearly mature. (989) In the northern states soybeans are used chiefly on sandy land or as a catch crop when clover or other crops fail. Moore and Delwiche of the Wisconsin Station[34] report that soybeans planted in June on jack-pine sand where sugar beets had failed produced 2 tons of hay per acre. Evvard of the Iowa Station[35] found soybeans or cowpeas surpassed for hog pasture by rape, clover, and alfalfa on soil where the later crops flourished.

[33]Morse, U. S. D. A. Farmers' Buls. 1148, 1153.

[34]Wis. Bul. 236.

[35]Iowa Bul. 136.

359. Vetch.—Only the *hairy vetch* (*Vicia villosa*), also called sand or Russian vetch, and the *common vetch* (*V. sativa*), also known as smooth or Oregon vetch, are important in the United States. Both are ordinarily annuals, tho the hairy vetch especially may live for more than a year. Being cool-weather plants, they are usually fall-sown in mild climates, but a spring strain of the common vetch is sometimes grown. While common vetch is killed by zero temperatures, hairy vetch usually endures the winter in the northern states if well established in the fall. Hairy vetch may be grown on poorer soil than its relative, is adapted to a wider range than crimson clover, and is markedly drought resistant. It is chiefly grown for hay, being usually sown with the cereals to support the weak vines, which clamber from 4 to 10 feet in a tangled mass. Harvested when the pods are full grown, a palatable hay is secured. According to Piper[36] the yield from vetch grown alone ranges from 1.5 to 2.5 tons or more of hay per acre. (**619**)

In the South and in western Washington and Oregon, where the winters are not severe, common vetch is preferred for soil rich enough for its culture, since the seed is cheaper and the vines grow less tangled. Piper places the yield of hay at 2.5 tons in the latter district and slightly less in the southern states. Smith of the United States Department of Agriculture[37] reports that at Atlanta, Ga., vetch and oat hay is popular with liverymen, selling on a par with cowpea hay. Besides furnishing hay, the vetches afford excellent pasturage for cattle, sheep, and swine. Smith reports the successful use of vetch silage for a dairy herd.

360. Lespedeza, *Lespedeza striata.*—*Japan clover,* commonly called *lespedeza* in the South, is a summer annual which has now spread over most of the territory from central New Jersey westward to central Kansas and south to the Gulf. Here, even on the poorest soils, it appears spontaneously as a common constituent of mixed pastures, and unless closely grazed reseeds itself from year to year. On the poorer sands and clays of the cotton belt lespedeza is perhaps the most valuable pasture plant, adding nitrogen to the soil, binding it together, preventing washing, and furnishing pasturage well-liked by all stock. This legume has not been known to cause bloat. Only on rich soils does it grow tall enough for hay. The crop is easily cured and in extreme cases yields 3 tons of hay per acre, which, according to Duggar of the Alabama Station,[38] is equal to alfalfa in feeding value. (**508**)

361. Velvet bean, *Stizolobium* spp.—Especially since earlier-maturing varieties of this plant have been developed, the culture of the tropical velvet bean has increased by leaps and bounds, until it is now one of the most important crops of the South, and is doing much to revolutionize the agriculture of the cotton belt. In 1919 over 4,200,000 acres of velvet beans were grown in the southern states.[39] The early-maturing varieties have matured seed as far north as Pennsylvania, while the original

[36] Forage Plants, p. 472. [38] Wing, Meadows and Pastures, p. 354.
[37] U. S. D. A., Farmers' Bul. 529. [39] U. S. D. A., Mo. Crop Reporter, Feb., 1920.

Florida velvet bean could not be grown north of a line from Savannah, Georgia, to Austin, Texas. Even the early varieties make a tangled mass of vines 3 to 10 feet long, while the late-maturing sorts run 15 to 40 feet. The crop is therefore difficult to cure into hay. The beans are usually planted with corn to support the vines, and the crop is commonly used for grazing, after most of the ears of corn and perhaps some of the ripe beans have been picked by hand. (**264**)

Velvet beans furnish excellent grazing for cattle and sheep, but the crop has not proved as satisfactory for pigs as was first expected. (**991**) Tracy[40] reports 20 acres of velvet beans in Florida furnishing half the daily grazing for 30 cows during 27 days in winter, after which 10 tons of pod beans were harvested. Eighty acres of velvet beans in southern Georgia furnished grazing for 100 head of cattle 4 months. Seventy days' grazing on velvet-bean pasture was sufficient to put steers in marketable condition. (**760**)

362. Peanut, *Arachis hypogaea.*—Peanuts are grown chiefly for the under-ground nuts (**258**), tho the entire plant is sometimes cured into a nutritious hay. According to Piper,[41] as a hay plant the peanut cannot compete with the soybean or the cowpea, but the plant is of great importance as a pasture crop for hogs, which root out the nuts. Hogs finished solely on peanuts yield a soft pork, but this may be largely avoided by feeding corn or other feeds. (**1005**) Since the nuts will not long remain in the ground without sprouting, the crop must be pastured soon after maturity. When peanuts are grown for the seeds, the straw is used for stock feeding, the yield ranging from 0.75 to 1.5 tons or more per acre.

363. Beggar weed, *Desmodium tortuosum.*—This annual legume, which has rather woody stalks 3 to 10 feet high bearing abundant leafage, is used for green forage and hay production in the sub-tropical regions of our country. Garrison of the South Carolina Station[42] reports a yield of over 11.5 tons of green and 2.25 tons of dry forage from 1 acre. Beggar weed should be cut for hay before the lower leaves drop off and the stems become too woody. Such hay is relished by stock, but the greatest value of the crop is for grazing.[43]

364. Miscellaneous legumes.—The *Tangier pea* (*Lathyrus tingitanus*), which is somewhat similar to the common sweet pea, but more vigorous in growth, has given promising results as a hay and green manure crop in the southern states and western Oregon.[44] *Serradella* (*Ornithopus sativus*), cultivated to a considerable extent in Europe on poor sandy land, has thus far attained no importance in the United States. As it will grow on soil too acid for other legumes, it may be found useful on acid sands in the northern states. The *moth bean* (*Phaseolus aconitifolius*), a native of India, is in many ways superior to the cowpea in northern Texas, according to Conner[45] being more drought resistant

[40]U. S. D. A. Farmers' Bul. 300.
[41]Forage Plants, p. 547.
[42]S. C. Bul. 123.
[43]U. S. D. A. Farmers' Bul. 1125.
[44]Wash. Bul. 2, Spec. Series.
[45]Tex. Bul. 103.

and curing more readily. The *hyacinth bean* or *bonavist* (*Dolichos lablab*), an annual resembling the cowpea but more viny, is often grown as an ornamental. It is of no especial promise as a forage crop except in the plains region of Texas, where it is apparently somewhat more drought resistant than the cowpea.[46]

The *Kudzu vine* (*Pueraria thunbergiana*) is a rapidly growing perennial vine which dies back to the ground each year. It is often grown as an ornamental in the South, where it reaches a length of 60 feet or more. Recent trials show it to be of considerable promise as a perennial forage crop for the Gulf region. Under field conditions the prostrate branches root at the joints and send up twining shoots 2 to 4 feet high, which may be readily cut with a mower. According to Piper,[47] in northern Florida 3 cuttings of hay a season have been obtained, the yield ranging from lower than velvet beans to as high as 10 tons per acre.

[46]Tex. Rpt. 1912.

[47]Forage Plants, p. 564.

CHAPTER XV

ROOTS, TUBERS, AND MISCELLANEOUS FORAGES

I. Roots and Tubers

In northern Europe and in eastern Canada root crops are extensively grown for stock, but in this country such use has never assumed any great importance. Indeed, over 5,000 acres of corn are raised in the United States for each acre of roots grown for live stock feeding. Having cool summers, northern Europe is well suited to the growth of roots but not to the culture of corn, while in most parts of our country, with the hot summers, this imperial grain and forage plant thrives. As shown later in this chapter, where corn flourishes it furnishes a palatable, succulent feed at less cost than do roots. Hence, it is reasonable to expect that in the United States the culture of roots for forage will increase only in districts having summers so cool that these crops give better returns than corn, and on farms in the corn belt where too few animals are kept to use corn silage economically, or where roots serve as a relish for show animals and dairy cows on official test.

365. Use and value of roots.—Roots should be regarded not as roughages, but as watered concentrates, high in available energy for the dry matter they contain. (22) All are low in crude protein compared to their content of carbohydrates. The studies of Friis[1] in Denmark and Wing and Savage at the New York (Cornell) Station[2] show that for the dairy cow a pound of dry matter in roots has the same feeding value as a pound of dry matter in grain, such as corn, wheat, or barley. (638) Wing and Savage found that mangels could replace half the grain ordinarily fed in a ration of grain, mixed hay, and silage without reducing the yield of milk or butter, and that with grain at $30 per ton, mangels were an economical substitute when they could be grown and stored for $4 per ton.

Since nearly 90 per ct. of the dry matter in roots and only 66 per ct. of that in well-matured corn silage is digestible, one would expect the dry matter of roots to have somewhat the higher value. However, in the majority of the trials in which this question has been studied with the dairy cow, just as much milk was produced from 100 lbs. of dry matter in the silage ration as in the ration containing roots. (638)

In addition to the nutrients they furnish, roots and other succulent feeds have a beneficial tonic effect upon animals, and are highly esteemed for keeping breeding cattle and sheep in good, thrifty condition. Many successful stockmen recommend roots highly for animals being fitted for

[1] Expt. Sta. Rec., 14, 1903, p. 801. [2] N. Y. (Cornell) Bul. 268.

exhibitions and for dairy cows crowded to maximum production on official tests. At the Michigan Station Shaw[3] and Norton found that when roots were added to a well-balanced ration containing good corn silage the yield of butter fat by dairy cows was increased 5.8 per ct. Yet this increase was not sufficient to offset the greater cost of the ration containing the roots. (**639**)

In this country the daily allowance of roots per 1,000 lbs. live weight is usually 25 to 50 lbs. or less. Thruout Great Britain fattening cattle and sheep are often fed 100 lbs., or even more, per 1,000 lbs. live weight daily with satisfactory results, and sheep are sometimes fattened on concentrates and roots alone. This practice can not be generally recommended, for better results are secured when some dry roughage is fed. Roots are usually chopped or sliced before feeding, and the cut roots are often put into the feed box and meal sprinkled over them. In feeding cattle in Canada and England, roots are quite commonly pulped and spread in layers several inches thick, alternating with other layers of cut or chaffed hay or straw. After being shoveled over, the mass is allowed to stand several hours before feeding, to moisten and soften the chaffed straw or hay. In this manner great quantities of straw may be successfully utilized. (**784, 786, 865**) For winter feeding in the northern states roots must be stored in well-ventilated pits or cellars, but in mild climates they may remain in the field until fed. In Great Britain sheep are often grazed on root crops, saving the labor of harvesting.

366. Roots vs. corn silage.—The most extensive of several trials in which the yields of roots and silage corn have been compared are summarized in the following table:

Yield of fresh and dry matter per acre of roots and fodder corn

Station	Mangels		Sugar beets		Rutabagas		Fodder corn	
	Green weight	Dry matter	Green weight	Dry matter	Green weight	Dry matter	Green weight	Dry matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Maine*.....	15,375	1,613	17,645	2,590	31,695	3,415	39,645	5,580
Penn.†.....	38,273	4,554	25,591	4,683	.....	.....	18,332	6,763
Ontario,‡ 5–8 yrs.	47,480	4,440	29,760	4,890	39,260	4,260	38,320	8,050
Average.....	33,713	3,536	24,332	4,054	35,478	3,838	32,099	6,798

*Woll, Book on Silage. †Penn. Rpt. 1898. ‡Ontario Dept. Agr., Bul. 228.

On the average, the corn crop contained 92 per ct. more dry matter than mangels, 68 per ct. more than sugar beets, and 77 per ct. more than rutabagas. At the Ohio Station[4] Thorne found that to grow and harvest an acre of beets yielding 15.75 tons and containing 3,000 lbs. of dry matter cost more than an acre of corn yielding 57 bushels of grain and containing 6,000 lbs., or twice as much, dry matter. In trials covering

[3] Mich. Bul. 240. [4] Ohio Rpt. 1893.

4 years at the New York (Cornell) Station[5] Minns found the cost of growing and ensiling silage corn about the same per ton as that for growing and harvesting mangels. However, owing to their watery nature 100 lbs. of dry matter in mangels cost over twice as much as in corn silage. These findings show that where corn thrives, corn silage will furnish dry matter at one-half the cost of roots or less. This is largely because root crops require more careful and thoro preparation of the soil and far more hand labor in cultivation, harvesting, and storage than does corn.

367. Yields of various root crops.—The most extensive comparisons of the yields of various root crops are those reported by the New York (Cornell) Station[6] from 5-year tests and by the Ontario Agricultural College[7] from trials covering 5 to 15 years, which are summarized in the following table. The yields from kohlrabi, cabbage, rape, and kale, which are sometimes included loosely under the term "root crops" are also given, along with the return from a 200-bushel crop of potatoes.

Yield and dry matter per acre in various root crops

	New York (Cornell) Station		Ontario Agr. College	
	Green wt. Tons	Dry matter Lbs.	Green wt. Tons	Dry matter Lbs.
Mangels	39.7	8,400	23.7	4,440
Sugar mangels	28.1	6,400	24.0	5,460
Sugar beets	28.3	8,000	14.9	4,890
Rutabagas (swedes)	26.3	5,000	19.6	4,260
Hybrid turnips	27.1	5,200	....	....
Turnips	16.8	3,600	27.2	5,160
Carrots	18.5	4,400	27.5	6,460
Parsnips	8.3	3,800	8.3	2,750
Kohlrabi	23.4	4,600	15.8	2,819
Cabbage	36.4	4,600	23.1	4,102
Dwarf Essex rape	....	....	17.2	5,758
Thousand-headed kale	....	....	17.7	4,000
Potatoes (200 bushels)	6.0	2,540	6.0	2,540

As is shown in the table, the rank of these various crops varies widely in different sections, depending on the climatic and soil conditions.

368. The mangel, *Beta vulgaris,* var.—Tho the mangel, or mangel wurzel, is the most watery of roots, it returns a large amount of dry matter per acre because of its enormous yield. The dry matter content of mangels averages 9.4 per ct. and that of the half-sugar mangels, which are crosses between the mangel and the sugar beet, is somewhat higher. Because it stands well out of the ground, the mangel is easily cultivated and harvested, and furthermore it keeps better in winter than does the sugar beet. Mangels should not be fed until they have been stored for a few weeks, as the freshly-harvested roots may cause scours. Mangels are useful for all farm animals, except possibly the

[5] N. Y. (Cornell) Bul. 317.

[6] Piper, Forage Plants and their Culture, p. 587.

[7] Ontario Dept. of Agr., Bul. 228.

Sugar Beets in a Western Irrigated District

While but relatively few acres of sugar beets are grown for stock feeding in this country, the raising of sugar beets for the beet sugar factories is an important industry in certain sections, especially in some of the irrigated districts of the West. (From U. S. Reclamation Service.)

Rape Excels as an Annual Forage Crop in the North

At small expense rape furnishes excellent forage for sheep, swine, or cattle from early summer to late fall.

Soap Weed (Yucca elata) in the Southwest

Several species of Yucca and Sotol furnish valuable emergency feed for range cattle in the Southwest in time of drought. See Page 251. (From U. S. Department of Agriculture.)

Singeing Prickly Pear with a Gasoline Torch

After the spines have been singed off cattle can feed on prickly pear without harm. Another method is to cut the cacti and run them thru machines which chop them, rendering the spines comparatively harmless. (From U. S. Department of Agriculture.)

horse. (638-9, 784, 864) Fed to rams or wethers for long periods, both mangels and sugar beets tend to produce dangerous calculi, or stones, in the urinary organs.

369. Sugar beets, *Beta vulgaris,* var.—This root has been marvelously developed for the single purpose of producing sugar, some strains now yielding 16 per ct. or more. The sugar beet demands more care in cultivation than the mangel and more labor in harvesting, as it sets deep in the ground. Sugar beets are esteemed by many dairymen as succulence for cows under test. If liberally fed, this root may induce scouring because of its high sugar content. Farmers patronizing sugar factories should utilize cull beets as well as the tops. Beet tops and leaves may be fed fresh or ensiled. Care must be taken when stock is turned on beet fields to forage, as decaying beet tops may poison the animals. According to Morton of the Colorado Station,[8] tho the tops keep better if cut, they may be ensiled whole if the mass is well packed. At the Wisconsin Station[9] Humphrey found that beet tops make good silage when run thru the silage cutter along with an equal weight of dry corn fodder, sufficient water being added so that the mass will pack well.

370. Rutabaga, *Brassica campestris.*—The rutabaga, or swede, ranks next to the mangel in ease of cultivation and harvesting. Sheep prefer it to all other roots. Like other turnips, the rutabaga may taint the milk of cows, and for this reason should be fed immediately after milking. This root is of vast importance to the stock interests of Great Britain and is likewise a favorite in Canada, where it is extensively grown. (511) In the central part of the corn belt and southward much of the growing season is too hot for rutabagas.

371. Turnip, *Brassica rapa.*—Turnips are more watery than rutabagas and do not keep so well. Hybrid turnips, crosses between the turnip and the rutabaga, keep better than ordinary turnips. Maturing early, turnips are used chiefly for early fall feeding. Sown as a catch crop, large yields are often secured without cultivation. Tho used mainly for sheep, they can also be fed to cattle.

372. Carrot, *Daucus carota.*—Under favorable conditions the stock carrot gives heavy yields. This root is relished by horses of all ages and conditions, but should not be fed in large amount to hard-worked or driving horses. (511) Carrots also serve well for other stock, especially dairy cows. Hills of the Vermont Station[10] writes: "Carrots far surpassed beets in feeding value."

373. Parsnip, *Pastinaca sativa.*—The parsnip is the favorite with dairymen on the islands of Jersey and Guernsey. It contains about as much dry matter as the sugar beet, but as the yield in this country is relatively low and the root difficult to harvest, it is little grown. (511)

374. Potato, *Solanum tuberosum.*—In Europe heavy-yielding varieties of large-sized potatoes are extensively grown for stock, but in this country potatoes are only fed when low in price or too small for market.

[8] Breeder's Gaz., 65, 1914, p. 115. [9] Wis. Bul. 228. [10] Vt. Rpt. 1907.

Knowing their feeding value, the farmer is in position to utilize the crop wisely, for feeding his live stock, rather than to force it on a profitless market. Potatoes are chiefly employed for swine feeding (**1001**), but may be fed in limited amounts to cattle, sheep, and horses in partial substitution for grain. For pigs the tubers should be boiled or steamed, and mixed with meal. The heavy feeding of raw potatoes is not advisable, as it induces scouring, but they may be fed in limited amounts sliced and mixed with dry feed. The bitter-tasting water in which potatoes are cooked should be thrown away, especially if the tubers are not sound. According to Pott,[11] potatoes may furnish half the dry matter in the ration for fattening cattle and sheep, and one-fourth for horses. (**511**) Milk cows should not be fed more than 30 to 35 lbs., as larger amounts injure the quality of the butter. (**640**) Unripe potatoes and especially the sprouts of stored potatoes contain considerable *solanin,* a poisonous compound; hence in feeding potatoes any sprouts should be removed.

In Germany where machinery for drying potatoes has been perfected, the dried product is quite extensively fed to live stock. To produce 1 ton of the dried *potato flakes* from 3.5 to 4.0 tons of raw potatoes are required.

375. Jerusalem artichoke, *Helianthus tuberosus.*—The tubers of this hardy perennial, which resemble the potato in composition, are sometimes used for human food and for feeding stock. The tubers live over winter in the ground and enough are usually left to make the next crop. Due to this the plant may sometimes become a weed. Goessmann of the Massachusetts Station[12] reports artichokes yielding at the rate of 8.2 tons per acre. They may be harvested in the same manner as potatoes, or hogs may be turned in the field to root out the tubers. At the Oregon Station[13] 6 pigs confined to one-eighth of an acre of artichokes gained 244 lbs., consuming 756 lbs. of ground wheat and oats in addition to the tubers. Allowing 500 lbs. of grain for 100 lbs. of gain, we find that an acre of artichokes was worth 3,700 lbs. of mixed wheat and oats. The pigs made but little gain on artichokes alone.

Pott[14] reports that the leaves and stems may be cut when half the leaves are still green, without reducing the yield of tubers. This forage may be fed to sheep, goats, or dairy cows with good results. Despite the many enthusiastic endorsements of artichokes no community in this country seems to grow them continuously—a significant fact. (**511, 1002**)

376. Sweet potato, *Ipomaea batatas.*—The sweet potato, a southern crop grown as far north as New Jersey and Illinois, serves not only for human food, but also for feeding stock, especially swine, which do their own harvesting. Tho the average yield is less than 90 bushels per acre, some farmers raise fully 200 bushels.[15] The sweet potato is at its best on sandy

[11]Handb. Ernähr. u. Futter., II, 1907, pp. 363, 366–7.
[12]Mass. Rpt. 10. [13]Ore. Bul. 54.
[14]Handb. Ernähr. u. Futter., II, 1907, p. 196.
[15]Duggar, Southern Field Crops, p. 449.

soil. Keitt of the South Carolina Station[16] states that land which under ordinary cropping yields but 20 bushels of corn will produce 200 bushels of sweet potatoes per acre. Dodson of the Louisiana Station[17] considers sweet potatoes the best root crop for hogs for fall and early winter grazing. (1004) Conner of the Florida Station[18] found that sweet potatoes may be successfully substituted for half the corn in the ration of work horses, 3 lbs. of sweet potatoes replacing 1 lb. of corn. Scott of the same station[19] found that 100 lbs. of sweet potatoes was as useful as 150 lbs. of corn silage for dairy cows. While more valuable, sweet potatoes were also far more expensive to produce than the corn silage.

The vines, tho difficult to gather because they trail and take root at short intervals, are often utilized for feed, usually in the green state.

377. Chufa, *Cyperus esculentus.*—The chufa sedge, frequently a weed in damp fields on southern farms, produces numerous small, chaffy, edible tubers. These are relished by pigs, which are usually turned in to harvest the crop. As chufas are low in digestible crude protein, protein rich feeds should be added to balance the ration. They grow best on light, sandy soils, yielding from 100 to 150 bushels of 44 lbs. each per acre. Like artichokes, the tubers remain in the ground uninjured thru the winter. Good crops of chufas have produced 307 to 592 lbs. of pork per acre, after making allowance for the other feed consumed by the pigs. (1006)

378. Cassava, *Manihot utilissima.*—Cassava, a bushy plant 4 to 10 feet in height with fleshy roots like those of the sweet potato, grows in Florida and along the Gulf coast. In the tropics varieties having bitter roots containing prussic acid are grown. These must be dried or heated before feeding. The sorts grown in the United States have sweet roots containing but a trace of prussic acid. From 5 to 6 tons of roots, carrying from 25 to 30 per ct. of starch, are produced per acre. They are used for the manufacture of starch and for cattle and swine feeding.[20]

Dodson[21] reports that in Louisiana a larger tonnage can be obtained from sweet potatoes than from cassava, and at about one-third the cost. This crop has never been important in the United States and its culture has declined greatly in the last 20 years. The cassava waste of starch factories should be dried for feeding. (785)

II. Miscellaneous Succulent Feeds

379. Cabbage, *Brassica oleracea.*—On rich ground cabbage gives as good returns of palatable forage as do root crops, but as more labor is required in its cultivation, it is but little grown for stock feeding. Cabbage is highly prized by shepherds when preparing stock for exhibition, and is also used for feeding milk cows, Gill of England[22] considering it superior to rutabagas. Like other plants of the mustard family it

[16] S. C. Rpt. 1909, p. 32. [17] La. Bul. 124. [18] Fla. Bul. 72. [19] Fla. Bul. 99. [20] U. S. Dept. Agr., Farmers' Bul. 167. [21] La. Bul. 124. [22] Jour. Brit. Dairy Assoc., 1898.

should be fed after milking to avoid tainting the milk. When cabbage is raised for market, the small heads and the leaves may be fed to stock.

380. Kohlrabi, *Brassica caulorapa.*—This member of the mustard family, which is valued for its thickened, turnip-like stem, can be grown wherever rutabagas thrive, tho the yield is usually lower. According to the New York (Cornell) Station[23] kohlrabi is a good substitute for rutabagas in the Middle West, where these roots have a tendency to run to neck and form little root. Kohlrabi stands well out of the ground and thus can be readily pastured by sheep, which also relish the leaves. This crop has not been known to taint the milk when fed to cows.

381. Rape, *Brassica napus.*—Largely thru the instrumentality of our experiment stations, rape is now extensively grown by stockmen thruout the United States. This member of the turnip family stores its nutriment in the numerous leaves and stems, the parts eaten by stock. The Dwarf Essex variety should be sown, birdseed rape being worthless. While rape can be used for soiling, it is best to let stock harvest the crop. Unless grown in rows, cattle will tramp down considerable of the forage while grazing. Rape is rarely used for silage. The seed, which is inexpensive, may be sown in succession from early spring until August in the North and even later in the South, either broadcast, in drills and cultivated, or finally with corn just previous to the last cultivation.

Rape requires a rich soil and plenty of moisture. It does not thrive on poor sandy land. From 6 to 12 weeks after seeding the crop is large enough for use. Zavitz of the Ontario College[24] reports a yield of 27 tons of rape forage per acre from 2 lbs. of seed sown in drills 27 inches apart, the crop having been cultivated every 10 days. In plot tests covering 15 years he secured an average yield of 19.2 tons per acre.[25] Rape endures quite severe frosts, therefore furnishing late autumn feed. It should never be eaten so closely that only the bare stalks remain, for the yield of new leaves will then be reduced. Animals on rape consume large amounts of salt, which should be freely supplied, as it tends to check any undue laxative effect of the forage. Sometimes stock must be taught to eat rape, but they later become fond of it.

Rape is used most largely for swine and sheep (**992, 874-5**), but also furnishes good grazing for cattle. To avoid tainting the milk of dairy cows, rape should be fed or grazed only directly after milking. Rape furnishes one of the best forages for hogs, and, as it somewhat more than maintains them, all the grain which is fed goes to make gain. The white breeds of swine sometimes suffer from a blistering of the skin if allowed to graze rape when the leaves are wet. In the northern states where field peas thrive, a mixture of rape, oats, and field peas may furnish even better grazing than rape alone. Access to grass pasture helps prevent bloat in sheep or cattle grazed on rape. (**874**)

[23] N. Y. (Cornell) Bul. 244. [24] Ont. Agr. College, Rpt. 19.
[25] Ont. Dept. Agr., Bul. 228.

382. Kale, *Brassica oleracea,* var. *acephala.*—Kale, a cabbage-like plant that does not form heads, is grown extensively for stock feeding in this country only in the northern Pacific coast district. Here, a large-growing variety, "thousand-headed kale" is considered the best fall and winter soiling crop for dairy cows and is also used for sheep and swine. On rich soil yields of 35 to 45 tons or more are secured.[26] Kale, like others of the mustard family, should be fed after milking to avoid tainting the milk.

383. Pumpkins, squashes, and melons.—The pumpkin, *Cucurbito pepo,* is often planted in corn fields and the fruits used as a relish for horses, cattle, and pigs. (**1003**) One ton of pumpkins, including seeds, equals in feeding value for dairy cows about 333 to 400 lbs. mixed hay or 800 lbs. corn silage.[27] Tho often cooked for swine, trials show equally satisfactory results with the raw pumpkins. As the seeds contain much nutriment, they should not be removed before feeding. Squashes and melons, especially pie melons, or citrons (also called cow melons), are sometimes fed to stock.

384. Sunflowers.—Recently a tall variety of sunflowers, Mammoth Russian, has attracted considerable attention as a silage and soilage crop. Especially in districts of the western states where the season is too short and cool for corn, quite favorable results have been secured, yields of 22 to 36 tons of green forage per acre having been obtained.[28] The crop is commonly drilled in rows and cultivated, and is ensiled when most of the plants are in bloom or even before. Sunflower silage resembles in composition silage from rather immature corn, but is somewhat higher both in crude protein and fiber and furnishes slightly less total digestible nutrients per 100 lbs. Sunflower silage has been fed with good to fair results to dairy cattle, beef cattle, sheep, and even brood sows. (**636, 783, 870**) In certain cases, however, the silage has proven unpalatable to stock. Sunflowers have also been used with success as a soiling crop. In humid districts, where sunflowers are often seriously injured by rust, their value compared with other silage crops has not been fully determined. Where good crops of corn or the sorghums can be grown for silage, sunflowers should be grown only in an experimental way until their value for a particular locality has been determined.

385. Apples and other fruits.—Windfall apples, pears, peaches, plums, oranges, figs, etc., may often be fed advantageously to stock and sound fruit may be thus used when prices are too low to warrant marketing the crop, for all farm animals relish these fruits. (**511**) Fruits contain somewhat more dry matter than roots, the chief nutrients being the sugars. Since they are low in protein, they should be used with protein-rich feeds. For dairy cows apples have about 40 per ct. of the value of corn silage, and apple pomace is practically equal to the same weight of corn silage. (**635**) In trials at the Utah Station[29] when fed with shorts

[26]Wash. Bul. 2, Special Series; Ore. Cir. 5. [27]Vt. Rpt. 1908; Mass. Bul. 174.
[28]Mont. Buls. 118, 131; Colo. Exten. Bul. 158a; Nev. Bul. 91. [29]Utah Bul. 101.

and skim milk to pigs 100 lbs. of apples equaled 9 to 15 lbs. of concentrates. Wilson of the Arizona Station[30] reports satisfactory gains with lambs fed ripe waste olives and alfalfa hay.

386. Spurrey, *Spergula sativa.*—On sandy land in northern Europe spurrey, which requires a cool, moist, growing season, is used as a catch crop for soilage and for green manure. The plant has proved of little value in this country, not being adapted to our hot summers.

387. Prickly comfrey, *Symphytum asperrimum.*—This plant, occasionally exploited by advertisers, is inferior to the standard forage plants.[31] When carefully cultivated it gives fair returns of forage which at first is not relished by cattle.

388. Mexican clover, *Richardsonia scabra.*—This annual, which is not a legume, is abundant on sandy land in sections of Florida and along the Gulf Coast, where it springs up spontaneously each summer after the manner of crab grass. It furnishes pasturage and, tho rather succulent, may be cured into hay.

389. Purslane, *Portulaca oleracea.*—The succulent weed of the garden, purslane, can often be used to advantage with swine. Plumb of the Indiana Station[32] fed brood sows 9 lbs. of purslane each daily, along with wheat shorts and hominy meal, and secured fair daily gains.

390. Tree leaves and twigs; hydrolized sawdust.—The small branches and leaves of trees are regularly fed to farm animals in the mountain regions of Europe where herbage is scarce, and in case of a shortage of feed they have been extensively used elsewhere. Tree leaves are more digestible than twigs, and the better kinds compare favorably with ordinary hay in feeding value. Leaves of the ash, birch, linden, and elder are valued in the order given. They are eaten with relish, especially by goats and sheep. These statements apply only to leaves gathered at the right stage and cured like hay. Leaves which turn brown and drop from the trees in autumn are worthless for feeding farm animals. *Brush feed,* consisting of ground and crushed twigs, stems, and leaves, is used in certain mixed feeds as an absorbent for molasses. (**288**)

Recent experiments have shown that by heating sawdust with dilute acid under pressure, a portion of the crude fiber is converted into more soluble compounds, including sugars. This *hydrolized sawdust* has considerable feeding value, at least for cattle. (**627**)

III. Plants of the Desert

Sagebrush, saltbush, and greasewood flourish on the plains of western America where alkali and common salt shut out many or even all of the ordinary forage plants.

391. Sagebrush and salt bush.—Writing of the Red Desert of Wyoming, Nelson[33] says: "The amount of sagebrush, *Artemisia,* spp., consumed in the desert, is simply amazing.... Whole bands (of sheep) will

[30]Ariz. Rpt. 19.
[31]Wis. Rpt. 1889.
[32]Ind. Bul. 82.
[33]U. S. Dept. Agr., Div. Agros., Bul. 13.

leave all other forage and feed on sagebrush for a day or two at a time. After that they will not touch it for some days, or even weeks."

Many species of saltbush, *Atriplex*, and greasewood, *Sarcobatus*, flourish on the western plains and furnish forage to range stock. The Australian saltbush, introduced into California and Arizona, has proven of much less value than first expected. It is less drought resistant than the native saltbushes and is rather unpalatable on account of its high salt content. Its chief value, where it thrives, is to furnish green feed late in summer when most other plants have become entirely dry. It makes fair soilage but has little value for hay.[34]

392. Yucca and sotol.—It has been recently found[35] that various species of *Yucca*, including soapweed and the Spanish bayonet, and also sotol, *Dasylirion*, spp., a near relative of the yuccas, furnish valuable emergency feed for range cattle in the Southwest. After burning the dry leaves off the stout, succulent yucca stems, the plants are chopped off, and the stem and tuft of green leaves finely chopped or shredded by special machines, and then fed to the cattle. The compact heads of sotol are used similarly. Cattle may be maintained on either of these emergency feeds alone thru long droughts when they would otherwise starve.

393. Russian thistle, *Salsola kali*, var. *tragus*.—The introduced Russian thistle, now growing over great areas of the plains east of the Rockies, is used to some extent for pasture and hay. The mature plants are woody and loaded with alkali. It should be cut when in bloom and quickly stacked. It may also be ensiled.

394. Cacti.—In western Texas, New Mexico, and Arizona, various cacti, principally prickly pear, *Opuntia*, spp., growing wild on the ranges, are used for feeding cattle, especially during periods of drought. The chollas and other types of cane cacti are also eaten by stock. Cacti grow but slowly unless the soil is good and there is reasonable rainfall during some part of the year. Because of its peculiar structure this plant can survive protracted drought, tho it makes little or no growth at such times. Under favorable conditions the prickly pear may be harvested about once in 5 years. Cacti may be fed where they grow by first singeing off the spines with a gasoline torch, after which the cattle eat them with apparent satisfaction. Under favorable conditions a man can singe the spines from 6 to 12 tons of standing "pears" per day. Sometimes the pears are gathered in wagons and put thru machines which chop them so the spines are rendered more or less harmless.

Prickly pears are less watery than roots, containing on the average 16.5 per ct. dry matter, of which 3.4 per ct. is ash, and are lower in protein but somewhat higher in nitrogen-free extract. The young joints are more watery than those which are 2 years old or over, and cattle are said to prefer those which are more mature. Cane cacti contain a higher percentage of dry matter than the prickly pears. Cacti alone do

[34]McKee, U. S. Dept. Agr. Bul. 617.

[35]N. Mex. Bul. 114; Tex. Bul. 240; U. S. Dept. Agr. Buls. 728, 745.

not provide a maintenance ration for stock. According to Vinson,[36] cattle in the deserts of Sonora, Mexico, subsist for 3 months of the year on little else than the fruits of cacti, but they become emaciated. When fed in large amounts with no dry feed, cacti tend to produce scours. As cacti are all low in protein, this forage should be supplemented by protein-rich feeds, such as alfalfa hay or cottonseed meal. From trials at the Arizona Station[37] Vinson concludes that 6 lbs. or more of cholla fruit with 0.5 to 0.75 lb. of alfalfa hay per day will maintain a sheep in a lean but healthy condition.

In a trial by Griffiths[38] cows fed 3 lbs. cottonseed meal and 8 to 12 lbs. of rice bran per head daily ate about 150 lbs. of singed prickly pear, 6 lbs. of pear equaling 1 lb. of sorghum hay in feeding value. A lot of 27 steers fed a ration of 96 lbs. chopped prickly pear and 4.4 lbs. of cottonseed meal gained 1.75 lbs. per head daily, requiring 55 lbs. of pear and 2.5 lbs. of cottonseed meal per pound of gain.

Spineless cacti, which during recent years have been extensively advertised, have long been known in Mexico and the Mediterranean countries. Most spineless varieties are not hardy where the temperature falls below 20° F. and are thus of limited value in the southwestern states. These cacti cannot survive on the open range because cattle will graze and destroy them, and moreover they must be enclosed by rabbit-proof fences, as these animals are fond of them. Griffiths[39] reports yearly yields of 20 to 25 tons of spineless cactus per acre without irrigation at Chico in the Sacramento Valley, California; this locality having an average rainfall of 23 inches. These yields were secured with expert cultivation and when a perfect stand was carefully maintained.

The chief importance of cacti will undoubtedly be to furnish emergency forage for stock in the semi-arid regions in case of drought, for these plants are able to utilize most efficiently small and irregular supplies of moisture. For this purpose plantations of the spiny cacti may be established on the open range, where they will be able to grow and hold their own until drawn upon in time of serious drought, for cattle will not graze them when other feed is reasonably abundant.

IV. Poisonous Plants

Only the briefest mention can be made of the leading plants poisonous to stock. One in trouble should consult a competent veterinarian or send suspected specimens to the experiment station of his state or to the United States Department of Agriculture.

395. Plants carrying prussic acid.—Prussic acid, a most deadly poison, has been found in over 200 species of plants, including the sorghums, the wild cherry, vetch, Java bean, flax, etc. The poison is not present as free prussic acid, but in the form of complex compounds, called glucosides

[36]Ariz. Bul. 67.
[37]Ariz. Rpt. 21.
[38]U. S. Dept. Agr. Bur. Anim. Indus., Bul. 91.
[39]U. S. Dept. Agr., Farmers' Buls. 483, 1072.

These must be broken down and the free prussic acid liberated, before poisoning occurs. However, these glucosides are readily decomposed by certain enzymes which are usually present in the plants. Therefore the prussic acid may be set free in the digestive tract of an animal eating plants containing these glucosides.

Normally the sorghums are entirely harmless, for they contain no prussic acid, or only such small amounts that no poisoning is produced. However, when plants of the sorghum family, including the grain sorghums, the sweet sorghums, and also Sudan grass and Johnson grass, are stunted by drought, prussic acid may accumulate in such quantities as to kill animals eating the plants. The affected stock often die in a few minutes after eating only a few mouthfuls of the forage, so poisonous is prussic acid. Cases of poisoning by the sorghums have been largely confined to the western semi-arid districts, which are especially subject to protracted droughts. Second-growth sorghum and that grown on rich soil are most apt to be poisonous when stunted.

The prussic acid largely disappears from sorghum when it is cured. Hence dry sorghum fodder or stover is practically always safe to feed. In the ensiling process the prussic acid is destroyed, so sorghum silage is entirely safe. In pasturing the sorghums the only way to prevent serious loss is to turn an animal of little value into the field first. If no poisonous effects are observed, the rest of the stock may then be allowed to graze the crop.

The leaves of the wild cherry are particularly fatal to cattle, especially when wilted.

396. Ergot.—The seeds of rye and many grasses are sometimes attacked by a fungus which produces enlarged black, sooty masses, known as ergot. Occasionally rye grain containing ergot, or hay or straw bearing the fungus severely injures cattle which are continuously fed thereon during winter. Ergot acts on the nervous system, depressing heart action and thereby restricting the blood circulation. In pregnant animals abortion is often caused. Affected animals have colicky pains and the circulation in the ears, the tip of the tail, and the feet may be stopped to such a degree that gangrene sets in and the diseased parts slough off. Animals showing symptoms of this trouble should have their feed changed to remove the cause, and be warmly housed and liberally supplied with nourishing food.

397. Forage poisoning.—From time to time serious losses of stock have occurred in various parts of the country, especially in the Central West, from forage poisoning, or blind staggers. It affects horses, mules, and cattle chiefly, and sheep less frequently. During the summer and fall of 1912 thousands of horses were killed by forage poisoning in the Mississippi valley, and local outbreaks have caused serious losses in recent years. The trouble occurs most frequently in animals fed corn silage or corn fodder or stover.

Graham of the Illinois Station has recently found that at least many

of the cases of forage poisoning are caused by feed contaminated with the bacteria which cause ptomaine poisoning in humans; i. e., *Bacillus botulinus*. He has isolated these bacteria from samples of spoiled silage, corn fodder, oat hay, wheat bran, wheat screenings, rice meal, and oats which had poisoned stock. While the dangerous feed is often spoiled or moldy, in some cases it is wholesome in appearance. Animals on pasture which have been forced to drink stagnant surface water have been affected with forage poisoning, doubtless due to the water having passed thru moldy vegetation. Suspected samples of feed should never be tasted by persons, as mere traces of the poison may prove fatal to humans.

Graham advises[40] that upon the appearance of the disease the feed should be changed immediately. "In some instances the detection of the feed causing the illness is accomplished with difficulty; and as a precautionary measure, therefore, all feeds should be exposed to sunlight and air for several hours before being fed, if new rations cannot be obtained. Hay and grain may be washed with water just before they are fed. This is sometimes a valuable supplement to exposure to air and light, and is accomplished in practice by placing the feed upon the ground, in alternate feed lots daily, after having sprinkled it with water. Grains are more conveniently cleansed by being immersed in a tank of water several hours and thoroly agitated before being fed. Pastures are not subject to artificial treatment, but continued non-use, assisted by natural influences, apparently renders them harmless in a few weeks."

Promising results have been secured in the early stages of mild forms of the disease by using a botulinus anti-toxin.

398. Corn stalk disease.—In the West at times cattle turned into stalk fields during the fall and winter are killed by a mysterious disease. Efforts to determine the cause have thus far been unsuccessful. The disease may be a form of forage poisoning, while some believe it is a form of hemorrhagic septicaemia. Cutting the corn, shocking the fodder, and feeding it after curing, is recommended as a means of avoiding the trouble.

399. Corn smut.—Corn smut is generally harmless to stock, tho animals eating very large amounts may be injured by it. At the Wisconsin Station[41] the senior author fed two cows on corn smut mixed with wheat bran, gradually increasing the amount until 32 ounces was supplied daily to each cow. At this point one refused her feed, but the allowance of the other was increased until 64 ounces, or 1 peck, was fed daily. This cow seemed to thrive on the great quantity of smut and was growing fat, when she suddenly sickened and died. In other experiments cattle have been fed smut without harmful effects.[42]

400. Loco poisoning.—Great numbers of horses, cattle, and sheep have been lost on the great ranges of western America thru "loco" poisoning

[40]Ill. Exten. Cir. 38. [41]Wis. Univ., Rpt. of Board of Regents, 1881.
[42]Mich. Bul. 137; U. S. D. A., Bur. Anim. Indus., Bul. 10.

brought about by eating certain legumes, known as "loco weeds." This form of poisoning has caused losses estimated at a million dollars in a single western state in one year. "Locoed" animals have a deranged nervous system and an uncertain and staggering gait. Horses which were formerly gentle become uncontrollable and shy violently at imaginary objects or leap high over some slight obstruction. Many animals acquire such a liking for the plants that they will eat nothing else. Eventually animals seriously affected, starve to death. Marsh of the United States Department of Agriculture[43] states that the most important point in handling animals upon a range where there are loco weeds is to see that they have an abundance of good feed. Then they will not usually start eating the loco plants. When the first symptoms of loco poisoning are observed, it is essential to remove the animals to a place where they can not get the plants. A good plan is to put them on alfalfa pasture, if any is available. All locoed animals are constipated and the alfalfa has a tendency to relieve this condition.

401. Castor bean.—The castor bean and the pomace remaining after the oil has been extracted contain a deadly poison. Castor beans or pomace accidentally getting into feeding stuffs sometimes cause mysterious deaths. Carnican[44] reports that exposing castor oil cake to the air for 5 or 6 days or cooking the seeds or cake for 2 hours destroys the poison.

402. Larkspurs.—Several species of larkspur, which cause serious losses of cattle that graze on them, are found upon the western ranges. Sheep eat the larkspurs without evil effects and horses generally leave the plants alone. The first symptom of larkspur poisoning usually noticed on the range is the sudden falling of the animal, accompanied by violent struggles. After a few minutes the animal may rise and walk away, without showing further effects. In serious cases the first fall is followed by a second, and that by a succession of falls. Eventually complete prostration, vomiting, and death occur.

403. Miscellaneous poisonous plants.—The common horsetail, water hemlock, poison hemlock, death camas, lupines, wild parsnip, cockle bur, woody aster, and many other plants are more or less poisonous to farm animals. As Marsh[45] points out, stock seldom eat poisonous plants by choice, but only when induced or compelled by the scarcity of other feed. When the grazing is short, animals should therefore be kept away from spots definitely known to be infested with such plants. In moving herds or flocks on the range special precautions should be taken when it is necessary to pass over a trail that has been used by many others, for all good feed will have been consumed, and the stock will eat whatever is left.

[43] U. S. D. A. Dept. Bul. 575; Farmers' Bul. 1054.
[44] Ann. Soc. Agr., Lyon, 1887.
[45] U. S. Dept. Agr., Farmers' Buls. 536, 720.

CHAPTER XVI

SILAGE—SOILAGE—THE PREPARATION OF FEED

I. Silage and the Silo

The preservation of beet leaves, beet waste, and other green forage by gathering into heaps or into earthen pits and covering with earth has long been practiced in Europe. For many years there has been considerable discussion as to who built the first silo in this country. Apparently Fred L. Hatch of McHenry County, Illinois, should receive this credit.[1] In 1873 he built a square silo, 10 feet by 16 feet and 24 feet deep—8 feet below ground and 16 feet above. The same year the silo was filled with corn silage and was used each year until 1919. In 1877 the French farmer, Goffart, published his "Manual of the Culture and Siloing of Maize and Other Green Crops," the first book of its kind, covering 25 years of practical experience. In 1879 Mr. J. B. Brown of New York gave American readers a translation of Goffart's book, and in 1880 Dr. J. M. Bailey issued "The Book of Ensilage, the New Dispensation for Farmers." In 1881 Professor I. P. Roberts[1a] at Cornell University, and the senior author[2] at the University of Wisconsin, built and filled the first silos used for experimental purposes in America. By these means silos and silage were brought prominently before the farmers of this country, and the interest which was awakened has steadily increased until the ensilage of fodders has become a factor of vast importance in American agriculture.

404. How ensiling preserves forage.—When green forage is packed firmly into an air-tight chamber, such as a silo, fermentations take place, caused both by the enzymes contained in the plant cells and by bacteria and yeasts carried into the silo on the forage. During these fermentations much of the sugar in the ensiled forage is broken down into organic acids, chiefly lactic acid (the acid in sour milk), with some acetic acid (the acid in vinegar), and traces of other acids. In these changes oxygen is taken up and carbon dioxid (carbonic acid gas) given off. At first the oxygen in the air which has been entrapped in the ensiled mass is used up, but if the mass has been well compacted, this is soon exhausted. The enzymes and bacteria then obtain the additional oxygen needed for these decompositions from the oxygen-containing compounds in the forage—chiefly the sugars. When the sugar in the forage has been changed into the acids the fermentation is checked, for the other

[1]Prairie Farmer, Jan. 28, 1922.

[1a]Information to the authors.

[2]Wis. Rpt. on Amber Cane and the Ensilage of Fodders, 1881, pp. 60-69.

carbohydrates are attacked to only a small extent. It is due to this that well-matured corn or sorghum makes less acid silage than immature plants, which contain more sugar. Even tho an excess of sugar is present, the fermentation comes to an end at length, for sufficient acid is finally produced to prevent both the further growth of the bacteria and yeasts and the action of the plant enzymes. During the fermentation processes the temperature rises somewhat, but if the mass has been well compacted, so that but little air is present, the temperature in the interior of the silo rarely reaches 100° F. The changes are therefore far less extensive than those which occur in the making of brown hay. (334)

Not only does the accumulation of acid automatically check the further action of the acid-forming enzymes and bacteria, but it also prevents the growth of undesirable putrefying bacteria, such as cause the decaying of meat. The poor-quality, foul-smelling silage which often results when such legumes as alfalfa, clover, or soybeans are ensiled alone is doubtless largely due to the fact that there is not enough sugar present in the plants to yield sufficient acid to check the growth of these putrefying bacteria. The high protein content of these plants also favors putrefaction.

After a few days the silage-making processes cease, and no appreciable changes will take place so long as the air is excluded. Instances are on record where silage made 12 to 14 years before has been found to be of excellent quality.

Tho the conversion of sugar into organic acids is the chief change which takes place in good silage, other decompositions also occur to some extent. A considerable part of the protein is broken down by enzymes into amino acids (11), the silage sometimes containing 2 or 3 times as much of these cleavage products as the original fodder. However, as this splitting of the protein into simpler compounds is similar to the digestion which takes place in the digestive tract of the animal, we need not suppose that the nutritive value is thereby necessarily impaired. (49)

405. Steaming silage.—It has sometimes been advocated that forage be steamed immediately after placing it in the silo, on the ground that the bacteria, yeasts, and enzymes are thereby destroyed, and the more or less perfectly sterilized mass thus preserved with little or no fermentation. However, Withycombe and Bradley found in digestion trials with cows at the Oregon Station[3] that steaming corn forage after ensiling reduced the digestibility of the dry matter 16 per ct., the crude protein 91 per ct., the ash 79 per ct., and the fiber, nitrogen-free extract, and fat to a slight extent. Hence, tho the steamed silage was admirably preserved and contained only half as much acid as ordinary silage, its feeding value was greatly reduced. (83)

406. Requisites of a good silo.—1. *Air-tight walls.* The silo walls must be air-tight, for if oxygen gains entrance the fermentations will continue and molds will grow, spoiling the silage. Such action takes place

[3] Ore. Bul. 102.

at the top of the silo where the mass is exposed to the air, but if the silage has been well packed and wet down, the impervious top layer of rotten material, which soon forms, prevents further entrance of the air. All doors must fit tightly, else the silage will spoil about the openings.

2. *Cylindrical shape.* In the early silos, which were rectangular structures, it was exceedingly difficult to pack the mass in the corners so that it would not spoil. With the devising of the cylindrical silo by King at the Wisconsin Station[4] this serious trouble was overcome, thereby greatly advancing the practice of ensiling forage plants. The cylindrical silo has now been commonly adopted, for besides the advantage of having no corners, it provides the largest cubic capacity for a given amount of building material, and the sides are strong and unyielding.

3. *Smooth, perpendicular, strong walls.* Unless the walls of the silo are smooth and perpendicular, cavities will form along the walls as the mass settles and the adjacent silage will spoil. The walls must be strong and rigid, for during the settling of the silage a great outward pressure is developed. This increases with the depth of the silo and, according to King,[5] reaches 330 lbs. per square foot of wall surface at a depth of 30 feet. After the silage has fully settled this lateral pressure ceases.

4. *Depth.* The early silos were shallow, and even tho the forage was well-tramped it was often necessary to weight the mass down to force out the air sufficiently. By making the silo deep the great pressure compacts all but the upper layers so that the losses thru fermentation are reduced to a minimum. The fact that the losses of nutrients are heaviest in the upper layers and surface of the silage is another reason for having the silo deep, because the loss per ton of total contents is thereby reduced. At the Wisconsin Station[6] King placed about 65 tons of green corn forage in an air-tight silo in 8 layers, and determined the loss in each layer, after standing from September to March. The dry matter lost in the respective layers was as follows: surface (eighth) layer, 32.5 per ct.; seventh layer, 23.4 per ct.; sixth layer, 10.3 per ct.; fifth layer, 2.1 per ct.; fourth layer, 7.0 per ct.; third layer, 2.8 per ct.; second layer, 3.5 per ct.; and bottom layer 9.5 per ct. While the surface layer lost over 32 per ct. of its original dry matter, the average loss in the first 5 layers from the bottom was less than 5 per ct., and the loss for the whole silo only 8.1 per ct.

407. Types of silos.—Silos may be constructed of wood, solid concrete, concrete blocks and staves, brick, stone, glazed tile, or sheet steel. In the semi-arid regions pit silos, preferably with cement lining and curb, are extensively used, but these are impracticable in humid climates. In the southwestern states silos are sometimes built of adobe, reinforced with wire and plastered with cement. The choice between the various types of construction, all of which make good silos when well-built, will depend upon local conditions.

This work can present only the primary principles relating to silo

[4]Wis. Bul. 28, issued July, 1891. [5]Wis. Bul. 83. [6]Wis. Bul. 83.

construction, advising those interested to secure from the state experiment stations or the United States Department of Agriculture instructions concerning the form, materials, manner of construction, etc., as detailed in bulletins which are available for the asking.

408. Advantages of silage.—The widespread use of the silo for the preservation of forage is easily explained when we consider the advantages this system offers, the more important of which are:

1. At a low expense silage furnishes high-quality succulent feed for any desired season of the year. For winter feeding silage is far cheaper than roots and is as efficient a feed, except possibly in the case of animals being fitted for shows or milk cows on forced test. (**109, 365**) For summer feeding, silage furnishes succulent feed with less bother and expense than do soiling crops. Dairy cows yield no greater product from soilage than from silage. (**420, 643**)

2. When crops are properly ensiled less of the nutrients are wasted thru the fermentations which take place than are lost when the forage is cured as hay or dry fodder. (**297, 298**)

3. Silage, even from plants with coarse stalks, such as corn and the sorghums, is eaten practically without waste. On the other hand from 20 to 35 per ct. of dry corn fodder, even if of good quality, is usually wasted.[7] The use of silage thus permits the keeping of more stock on a given area of land, a factor of much importance on high-priced land.

4. Crops may be ensiled when the weather does not permit of curing them into dry fodder. In some sections of the South it is almost impossible to preserve the corn crop satisfactorily as grain and stover on account of the humidity, and also because rodents and weevils cause great loss in the stored grain.[8] Preservation as silage obviates both difficulties.

5. Weedy crops which would make poor hay may make silage of good quality, the ensiling process killing practically all the weed seeds present.[9]

6. The product from a given area can be stored in less space as silage than as dry forage. A cubic foot of hay in the mow, weighing about 5 lbs., contains approximately 4.3 lbs. of dry matter. An average cubic foot of corn silage from a 30-foot silo, weighing about 39.0 lbs., will contain 10.2 lbs. dry matter, or nearly 2.5 times as much. Dry corn fodder takes up even more space per pound of dry matter than hay. In climates where it is necessary to store fodder under cover this may be an added reason for the use of the silo.

409. Crops for the silo.—The suitability of the leading crops for silage has been discussed in detail in the foregoing chapters. Where it thrives Indian corn is the best silage plant. (**296**) The sorghums, including both the sorghos and the grain sorghums, are next in value and importance, as crops for silage. (**309**) In England meadow grasses have

[7] Skinner and Cochel, Ind. Bul. 129.
[8] Ferris, Miss. Bul. 158.
[9] Washburn, Vt. Bul. 170.

been converted into stack silage, in which case the decaying outside protects the interior of the mass—a practice which, however, is not gaining favor. Potts of Australia[10] reports that 3 tons of grass silage is estimated to be worth 1 ton of oat hay. A stack containing 200 tons of grass silage, opened after 10 years, furnished good feed. Georgeson of the Alaska Experiment Station[11] reports that fresh native grasses kept well when stored in a log silo made smooth inside, and that such silage satisfactorily maintained oxen during 3 winters. Green cereals are fairly satisfactory for silage, providing they are ensiled before the stems have become woody. (318) Since the hollow stems of these plants contain air, such forage must be closely compacted in the silo.

As a class the legumes have often proved disappointing for silage when ensiled alone. Therefore, except where weather conditions prevent curing alfalfa or clover into satisfactory hay or other more satisfactory silage crops can not be grown, they can not be recommended for silage. In ensiling these crops the directions given previously should be followed. (342, 348) Red clover usually makes better silage than alfalfa. When ensiled with corn or the sorghums, cowpeas and soybeans produce silage of high quality, rich in protein. (357-8) The refuse of pea canneries makes a silage much relished by farm animals. (356)

Such substances as beet pulp, beet tops, apple pomace, the waste from sweet corn canneries, and sorghum bagasse may be successfully ensiled in silos, or placed in heaps and covered with earth, or, if no better provision can be made, massed in large heaps without covering, in which case the outside portion on decaying forms a preserving crust. (275, 356) Cooke of the Vermont Station[12] found that ensiled apple pomace was preferred by cows to either hay or corn fodder, and concludes that it has a value equal to corn silage for cows. (635) Boyce of Australia[13] reports prickly pears making silage relished by cattle, the thorns softening and becoming harmless. Weeds and other waste vegetation may sometimes be advantageously ensiled. Featherstonhaugh of Australia[14] reports a case where 800 tons of ensiled thistles made satisfactory silage. Attempts to ensile cabbage and turnips have failed, the products being ill-smelling and watery. As discussed in another chapter (384), the large Russian variety of sunflowers is proving a satisfactory silage crop in certain sections.

410. Cost of silage.—The cost of silage per ton will vary widely depending on the price of labor, the yield of forage per acre, rent of land, etc. The following summary of data from 4 experiment stations gives the approximate ton and acre cost under conditions before the war of growing a silage crop and placing it in the silo. Tho the cost will differ quite widely thruout the United States, this summary will be help-

[10]N. S. Wales Gaz., Vol. 15, p. 82.
[11]Alaska Bul. 1.
[12]Vt. Rpt. 1903.
[13]N. S. Wales Gaz., Vol. 8, p. 505.
[14]N. S. Wales Gaz., Vol. 9, p. 71.

SAVING ALL OF THE CORN CROP BY ENSILING IT

Over a great part of the United States silage has well-nigh revolutionized stock feeding. The silo provides high-quality succulent feed for any season of the year, with a low expense for labor and a minimum wastage of nutrients.

SOILAGE IS USUALLY LESS ECONOMICAL THAN SILAGE

Providing succulent feed in summer by a succession of soiling crops is usually more expensive than the use of silage, chiefly because it requires more labor. (From Wisconsin Station.)

THE WHOLE FAMILY HELPS TO GRIND GRAIN

Even when grain is ground on the farm, the cost is quite an item. Therefore it is important to know whether the feeding value will be increased enough to make grinding profitable. See Page 270.

SHREDDING CORN STOVER INCREASES THE FEEDING VALUE

Shredding or cutting stover or dry fodder from corn or the sorghums is usually profitable, as the stock then waste much less of it. See Page 270.

ful in estimating the cost of silage under present conditions in various districts of the country.

Cost per acre of corn silage

	Minnesota Station,[15] 201 acres Dollars	Illinois Station,[16] 147 acres Dollars	Ohio Station,[17] 115 acres Dollars	New Jersey Station,[18] 80 acres Dollars
Land rental	3.75	5.28	3.81	.....
Manure or fertilizers	....	3.73	1.46	10.15
Seed	1.06	0.42	0.28	
Labor growing and cutting crop	5.19	12.26	14.63	8.27
Labor filling silo	4.12			
Twine	0.36	0.41	0.18	
Coal	0.42	0.46	0.25	10.84
Rental of power for cutter	1.39	1.21	1.36	
Interest and depreciation on farm machinery	1.56	1.76	1.34	....
Miscellaneous	1.13	0.58	0.42	....
Total cost per acre	18.98	26.11	23.73	29.26*
Cost per ton	.....	3.30	.....	3.65*

* Not including rent and interest and depreciation on farm machinery.

[15] Minn. Bul. 145. [16] Unpublished data. [17] Ohio Bul. 266. [18] N. J. Rpt. 1913, pp. 414-415.

Carrier of the United States Department of Agriculture,[19] collecting data from 31 Wisconsin and Michigan farms, found that 3.3 to 7.4 tons of corn forage was placed in the silo daily for each man employed.

The value per ton of corn silage for the various classes of stock is shown in later chapters. For dairy cows, good corn silage is worth about one-third as much as legume hay. (**631**) In trials with fattening cattle 1 ton of corn silage saved 227 lbs. corn and other concentrates, and 605 lbs. legume hay. (**775**) With fattening lambs 1 ton of silage saved 144 lbs. corn and 930 lbs. legume hay. (**867**) With concentrates at $20 per ton and legume hay at $14 per ton, good silage is thus worth $6.50 per ton for fattening steers and $7.95 per ton for fattening lambs.

411. Silage on the stock farm.—The use of silage has practically revolutionized the feeding of dairy cattle over a large part of the United States, and is fast assuming equal importance for the feeding of beef cattle and sheep. This succulent feed tends to keep the bowels normal, the body tissues sappy, the skin pliant, and the coat glossy, all of which mark the animals as in condition to make the most from their feed. (**109**) Furnishing at any time of the year a uniform supply of succulence nearly equal in palatability and nutritive effect to the pasturage of early summer, silage is eminently suited to the dairy cow. (**629-36**) As shown by the trials reviewed in later chapters, thru the wise use of silage for fattening cattle and sheep the cost of meat production may be materially lowered. (**774-83, 866-70**) Silage is especially valuable for breeding stock and young animals, which would otherwise often be wintered exclusively on dry forage. On too many farms stock cattle barely hold their own during winter. This means that for half of each

[19] U. S. Farmers' Bul. 292.

year all the feed consumed goes for body maintenance, returning nothing to the owner, and serving only to carry the animals over winter and to pasture time, when they once more begin to gain in weight and thereby really increase in value. By the use of corn silage, combined with other cheap roughages, young cattle can be made to gain steadily all winter at small cost, so that with the coming of spring they will not only have increased in weight but are in condition to go on pasture and make the largest possible gains.

Silage is a valuable succulence for the breeding flock, but must be fed in moderation to ewes before lambing or weak, flabby lambs may result. (884) Good silage may also be used in a limited way with idle horses and those not hard worked in winter, especially brood mares and colts. (510) Spoiled, moldy silage should always be discarded, and special care must be taken to feed no such material to sheep or horses, which are more easily affected thereby than are cattle.[20] (397) Silage which is unduly sour is apt to cause digestive disturbances with sheep. For all animals only as much silage should be supplied as will be cleaned up at each feeding. Care should be taken to remove any waste, for silage spoils in a short time on exposure to the air. Frozen silage must be thawed before feeding. If then given before any decomposition takes place no harm will result from its use.[21]

The amount of silage commonly fed per head daily to the various classes of stock is about as follows:

Dairy cows, 30 to 50 lbs. for those in milk, with somewhat less for dry cows; dairy heifers, 12 to 20 lbs.; beef breeding cows, 30 to 50 lbs.; fattening 2-year-old steers, 30 to 40 lbs. at the beginning of the fattening period, the allowance decreasing as they fatten until only 10 to 20 lbs. is fed; brood mares and idle horses, 10 to 15 lbs.; breeding ewes, 2 lbs. (sometimes as much as 3 to 4 lbs. is safely fed); fattening lambs, 1.5 to 3 lbs.

On high-priced land and with high prices ruling for purchased concentrates and for labor, the farmer will find the legumes and Indian corn or the sorghums his best crop allies. With an abundance of corn or sorghum silage and legume hay, the stockman need supply only the minimum of rich concentrates. With this combination of feeds the number of animals the farm will carry is greatly increased, to the great advantage of both land and owner, and the cost of producing meat and milk is cut to the minimum.

412. Summer silage.—In many districts summer droughts frequently injure the pastures, making necessary the supplying of additional feed to maintain satisfactory production with dairy cows and other farm animals. Especially on high-priced land, where intensive agriculture must be followed, it is often desirable to keep more animals than can profitably be maintained entirely on pasture during the summer. Silage will admirably meet both these needs where enough animals are kept to feed off 2 inches or more of silage each day so that the surface will not decay. (420)

[20] Ill. Exten. Cir. 38.

[21] U. S. Farmers' Bul. 556.

In trials covering 3 years at the Wisconsin Station[22] Woll, Humphrey, and Oosterhuis compared corn silage and soilage as summer supplements to pasture for dairy cows. In the production of milk and butter fat the silage ration was as efficient as that containing soilage, and also far cheaper and more convenient. (**643**) To provide a succession of green feed for animals by means of soiling crops it is necessary to fit and plant comparatively small areas to different crops at different times. As the cut soilage will quickly heat in warm weather if placed in piles and will then be less palatable, a supply must be harvested each day or at least about every 2 days. Harvesting in small quantities and in all sorts of weather is inconvenient and expensive, and moreover the work must be done at the busiest season of the year. On the other hand, when corn or the sorghums are grown for silage the large fields are fitted, planted, cultivated, and harvested with labor saving machinery at a minimum expense, and feeding the silage takes but a few minutes daily.

Corn and sorghum return greater yields of nutrients than many of the crops it is necessary to include in a soiling system. Silage furnishes feed of uniformly high quality thruout the season, a goal which is difficult to attain by soiling, for one crop is often exhausted or too mature before the next is in prime condition for feeding. The years when drought is severe and pastures unusually short are the very times when soiling crops will be scant or may even fail. By means of the silo, the crop may be carried over from one year to the next, thus providing insurance against drought.

413. Filling the silo.—Provided the material is closely packed, it is not essential that green forage be cut into bits to preserve it in the silo. The legumes, such as alfalfa, clover, cowpea vines, etc., are often ensiled uncut, and some farmers ensile whole corn forage, tied in bundles. Especially with such coarse material as corn or sorghum, the forage packs much better when cut into short lengths by passing thru a silage cutter. For this reason and because of the greater ease in filling and especially in removing the silage, most silage crops are commonly cut before being ensiled, preferably into one-half to one inch lengths. If cut longer than this stock may refuse the coarser portions of corn or sorghum silage.

When filling the silo the inpouring material should be thoroly mixed and evenly spread, so as to prevent uneven settling, as well as to make the mass uniform for feeding. As the friction of the walls retards the settling of the adjacent forage, material here should be kept slightly higher than in the center and should be especially well-tramped. The silage settles best when several days are occupied in filling the silo, for time is required for the forage to soften and settle and to expel the entangled air thru heat and the generation of carbon dioxid. After the mass has settled considerably, more forage may be placed in the silo, but any spoiled material should first be removed. If feeding is

[22] Wis. Bul. 235.

not to begin immediately, the surface should be wet down thoroly and tramped well several times the first week, when an impervious layer of rotten silage will form on top and only a few inches will be spoiled. To lessen the waste it is well to remove the ears from the last few loads of corn. A covering of a foot or so of cheap refuse, such as straw, weeds, or corn stalks, wet with water, will save the more valuable forage underneath. The crust should not be disturbed until feeding commences, when all spoiled silage should be discarded. Certain patent silo seals reduce the surface losses. When the forage becomes dry before being ensiled, water should be added either to the mass in the silo or preferably to the cut forage as it passes thru the blower.

414. Danger from carbon dioxid.—In silo filling there is possible danger to those who go into the pit after an intermission, due to carbon dioxid, or carbonic acid gas, which sometimes accumulates in sufficient quantity to prove fatal to life. The possibility of danger may be ascertained by lowering a lighted lantern or candle into the pit. If the light continues to burn at the bottom human beings can live in the same atmosphere, but if it goes out it means death to one entering the pit. The opening of a door low down in the silo will allow the poisonous gas to pour out, or pouring a lot of cut forage into the pit soon creates a circulation which removes the danger.

415. Weight of silage.—For many years in estimating the capacity of silos, tables based upon the work of King at the Wisconsin Station[23] have commonly been used. Recent extensive investigations by Eckles at the Missouri Station and Reed and Fitch at the Kansas Station[24] have shown that these tables overestimate the average capacity of silos. They found that the weight of a cubic foot of silage varies quite widely, depending on several factors, the average of their results being as follows, for silage after settling one month or more:

The weight of a cubic foot of corn silage at the surface foot was 32.0 lbs.; at a depth of 5 feet, 34.8 lbs.; at 10 feet, 38.0 lbs.; at 20 feet, 41.0 lbs.; and at 30 feet, 43.0 lbs. The average weight of the silage for the whole depth was 33.4 lbs. per cubic foot for the first 5 feet, 35.0 lbs. for a depth of 10 feet, 37.5 lbs. for a depth of 20 feet, and 39.0 lbs. for a depth of 30 feet.

416. Capacity of silos.—The following table condensed from the data of Eckles, Reed, and Fitch and of Chase of the Nebraska Station[24a] shows the estimated tonnage of silos for well-matured corn silage. The first division shows the estimated tonnage when the silage has been well tramped and allowed to settle one day, and the silo then refilled. The last division shows the estimated tonnage when the silage has settled for one month or more. The depth of silage in the table is the actual depth of silage and not the height of the silo wall. This table may be used for sorghum silage as well as for corn silage.

[23] Wis. Bul. 59.

[24] Results published jointly in Mo. Bul. 164 and Kan. Cir. 89. [24a] Neb. Cir. No. 1.

This table shows, for example, that when filling is completed in a silo 14 feet in diameter, filled to a depth of 30 feet, there will be about 80 tons of silage. If the silage is 26 feet deep after settling in a silo 12 feet in diameter, there will be about 56 tons of silage.

To estimate the amount of silage remaining in a silo after part has been fed out, find the actual depth left and estimate the original total depth of silage after settling. Then compute the amount as follows: Let us suppose that 10 feet of silage is left in a silo having a diameter of 14 feet, and that after settling one month the entire depth of silage was about 28 feet before feeding started. From the table we find that at first the silo contained 83 tons. The first 18 feet of silage, which was fed out, would weigh about 51 tons, according to the table. The difference, or 32 tons, is the approximate weight of the silage left.

Approximate capacity of cylindrical silos in tons of corn silage

*A. Capacity when filling is completed.**

Inside diam. in feet	Depth of silage in feet											
	18	20	22	24	26	28	30	32	34	36	38	40
10	20	23	26	30	33	37	41	...	...	...	...	...
12	28	33	38	42	48	53	58	64	70	...	...	...
14	38	45	51	58	65	72	80	87	95	103	111	120
16	50	58	67	76	85	94	104	114	124	135	145	156
18	64	74	84	96	107	119	132	144	157	171	184	198
20	78	91	104	118	132	147	162	178	194	211	227	244
22	95	110	126	143	160	178	196	215	235	255	275	296

*B. Capacity after silage has settled one month or more.***

	Depth of silage in feet											
	8	10	12	14	16	18	20	22	24	26	28	30
10	11	14	17	20	23	26	29	33	36	39	43	46
12	16	20	24	29	33	38	42	47	52	56	61	66
14	21	27	33	39	45	51	58	64	70	77	83	90
16	28	35	43	51	59	67	75	84	92	100	109	118
18	35	44	54	64	75	85	95	106	116	127	138	148
20	43	55	67	80	92	105	118	130	144	157	170	184

* A. If corn is unusually dry when ensiled, deduct 10 per ct. from the capacity given. If corn is dry and very little grain is present, deduct 15 per ct. If silo is filled rapidly and no time is allowed for settling, deduct 10 per ct.

** B. For corn ensiled when less mature than usual add 10 to 15 per ct. to the capacity given. If corn is unusually rich in grain, add 5 to 10 per ct. If corn is unusually dry when ensiled, deduct 10 to 15 per ct. If very little grain is present, deduct 10 per ct.

417. Proper size of the silo.—The diameter of the silo should be gauged by the number and kind of animals to be fed from it, and its height by the length of the feeding period. The silo should be of such diameter that in the cooler part of the year at least 1.5 inches, and preferably 2 inches, of silage will be removed from the entire surface daily to keep the surface from spoiling. When silage is used for summer feeding somewhat more should be removed daily. The exact size of silo required may be computed from the length of the feeding period and the amount required daily for the different kinds of stock, as shown on Page 262 and in the respective chapters of Part III. Knowing the number of animals of each

kind to be fed, the entire amount of silage which will be consumed daily may be ascertained. The maximum diameter which the silo should have may then be determined from the following: Two inches in depth of ordinary corn silage weighs about 5 lbs. per surface square foot near the top of the silo and 7 lbs. near the bottom, averaging about 6.5 lbs. in a silo filled to a depth of 30 feet. To use 2 inches daily from the surface, approximately the following amounts must be fed from silos of various diameters: Diameter 10 feet, 510 lbs. silage; 11 feet, 615 lbs.; 12 feet, 735 lbs.; 14 feet, 1,000 lbs.; 16 feet, 1,305 lbs.; 18 feet, 1,655 lbs.; 20 feet, 2,045 lbs.; 22 feet, 2,470 lbs.; 24 feet, 2,940 lbs.; 26 feet, 3,450 lbs. In cold weather and when the silage is well packed, a somewhat smaller amount may be removed daily.

When the minimum diameter which the silo should have has thus been determined, the total amount of silage required for the desired feeding period may be computed and the dimensions for a silo of this capacity found by referring to the table in the preceding article. It should be borne in mind that silage in a relatively deep silo keeps better than in a shallow one, and that a deep silo is the most economical to construct. King[25] found that a silo 36 ft. in depth will store 5 times as much feed as one 12 ft. deep, due to the greater compactness of the stored mass. Many silos are now built 40 ft. or even more in depth. A silo 20 ft. in diameter will hold 4 times as much as one having half that diameter, while it costs but twice as much to build. Gurler[26] advises against silos over 25 ft. in diameter on account of the increased labor involved in removing the silage.

II. Soilage

Soilage means supplying forage fresh from the field to animals in confinement. It was first brought to public attention in this country by Josiah Quincy, whose admirable essays, printed in the *Massachusetts Agricultural Journal* in 1820, were later gathered into a booklet entitled "The Soiling of Cattle," long since out of print. Soilage, one of the most intensive forms of husbandry, is especially helpful where it is desired to concentrate labor and capital in maintaining farm animals on a relatively small area of land.

418. Advantages and disadvantages of soilage.—Compared with allowing animals to gather their food by grazing, soiling has the following advantages: 1. With all crops, even grasses, which soon spring up again when grazed, a larger yield is secured by allowing the plants nearly to mature before harvesting than by pasturing them.[27] (**310**) 2. With a properly planned succession of soiling crops an abundance of palatable feed may usually be supplied thruout the season, so that the production of the animals will not decline if pastures become parched in midsummer. 3. None of the forage is wasted thru being tramped down by the animals or fouled with manure. 4. Less fencing is required.

[25]Physics of Agriculture. [27]Largely from Quincy, The Soiling of Cattle.
[26]The Farm Dairy.

The greater expenditure for labor, seed, and fertilizer in producing the crops and for labor in cutting and carrying them to the animals are the chief disadvantages of soilage. In warm weather soilage will ferment and mold in a short time if left in piles. When but few animals are fed the green forage may be spread thinly on the barn floor, where it will keep, but soilage thus handled dries out and is less palatable. Where a considerable quantity is harvested at one time much labor may be saved by using the mower and horse rake. During wet spells the palatability of the soilage is reduced, and it is difficult to harvest and cart the food to the animals without injury to the land. On the other hand, pastures also suffer if grazed while wet.

419. Yield of pasturage and soilage.—Quincy reports that he maintained 20 cows in stalls, allowing exercise in an open yard, on the soilage from 17 acres of land where 50 acres had been required when the land was pastured.

The senior author[28] kept 3 cows for 122 days in summer on 3.7 acres of excellent bluegrass pasture at the Wisconsin Station and maintained 3 others in stable and yard for the same period by feeding soiling crops (green clover, fodder corn, and oats) from 1.5 acres. On this area a total of 44,835 lbs. of green forage was produced. The product from an acre under each system was as follows:

Yield of milk and butter from 1 acre of soiling crops and pasture

	Milk per acre Lbs.	Butter per acre Lbs.
From 1 acre of soiling crops	4,782	196
From 1 acre of pasture	1,780	82

This shows that in Wisconsin 1 acre of soilage crops equalled about 2.5 acres of good bluegrass pasture for feeding dairy cows.

Otis of the Kansas Station[29] found that it required 0.71 acre of soiling crops, half the area being alfalfa, to furnish a cow roughage for 144 days, while, when the cow was grazed, during the same period it required 3.6 acres of pasture composed of prairie and mixed grasses. After allowing for the grain consumed, soilage returned $18.08 and pasturage $4.23 per acre. Voorhees[30] found that to produce a ton of dry matter in soiling crops yielding from 3 to 4.5 tons of dry matter per acre annually, cost on an average $6.50, and that the total cost per ton of dry matter, including cutting and hauling to the barn, would be about $9.00.[31] The feeding value of this dry matter was nearly equal to that in purchased concentrates costing over $20 per ton.

420. The place of soilage on American farms.—It has been shown before (412), that silage is a more economical means of supplying succulent feed in summer than is soilage. On farms where too few animals are kept to prevent the molding of the surface of the silage as it is fed off or where a silo is not available, soilage should be provided to prevent

[28] Wis. Rpt. 1885. [29] Kan. Press Bul. 71. [30] Forage Crops. [31] N. J. Rpt. 1907.

the usual midsummer shrinkage in milk flow with cows, and in flesh with beef cattle or sheep. Under this system animals may be housed in darkened stables away from the flies during the heated portion of the day and fed liberally with fresh cut soilage, being turned to pasture at night for exercise and grazing. Young cattle will then continue growing, steers will increase in fatness, and cows yield a normal flow of milk during a period of the year when, because of heat, flies, and scant pastures, there is quite commonly no profit, and sometimes serious loss. It is also often advantageous to supply extra green forage during the fall months, even tho the pastures have then partly recovered their ability to supply nutriment.

Because of the high price of labor in this country, it is not usually economical to maintain cattle in summer on soilage or silage with no pasturage in regions where good summer pastures may be provided. On high-priced land where it is desired to keep as many animals as possible on a given area such a system may be the most profitable. In Europe, where labor is relatively cheap compared with land, a much wider use can economically be made of soilage.

421. Crops for soilage.—A long list of crops are well suited for soilage, including the various legumes, such as alfalfa, the clovers, field peas, cowpeas, and soybeans; the cereals, as rye, wheat, barley, and oats; the smaller grasses; and especially corn—sweet corn for early feeding and field corn later—and the sorghums. The adaptability of all these for soilage has been discussed in the preceding chapters.

Soiling crops should not be fed until reasonably mature. Green, immature plants are composed largely of water, and often cattle cannot consume enough of them to secure the required nourishment. (**23, 310**) For this reason, where quite green crops are fed, some dry forage should also be supplied.

422. A soiling chart.—Wherever soilage is practiced, a succession of crops must be carefully planned so that a continuous supply of green forage of the proper stage of maturity will be available over the period desired. This must be worked out by each farmer, bearing in mind the yields and seasons of maturity of the various crops which are suited to his soil and climatic conditions. In such planning it is helpful to prepare a soiling chart, similar to the following, worked out by Voorhees of the New Jersey Station,[32] which will show the area of each crop to be grown, the date of seeding, the period of feeding, and the estimated yield. Any attempt in this line will be more or less imperfect at first but may be modified from growing experience and close study to meet the local conditions.

This chart is an example of a practical system of soilage, since it records the actual attainment of one who most successfully specialized in this system for many years. The results here reported were obtained upon lands once regarded as of low agricultural value, brought to high

[32] Forage Crops, p. 35.

productiveness by systematic soilage and fertilization. The table shows that 24 acres of land, producing 2 and sometimes 3 crops during the season, yielded 278.3 tons of green forage, supplying an average of 60.4 lbs. of green forage daily per head to an equivalent of 50 dairy cows from May 1 to November 1, a period of 6 months.

Soiling crops grown at the New Jersey Station for the support of a herd equal to 50 dairy cows for 6 months

Crops grown	Total seed used	Date of seeding	Period of cutting and feeding	Total yield
	Bushels			Tons
Rye, 2 acres	4.0	Sept. 27	May 1– 7	9.4
Rye, 2 acres	4.0	Oct. 3	May 7–19	19.2
Alfalfa, 1 acre, 1st cutting	0.6	May 14	May 19–25	11.1
Wheat, 2 acres	4.0	Sept. 26	May 25–June 1	10.4
Crimson clover, 6 acres	1.2	July 16	June 1–21	42.8
Mixed grasses, 1 acre	.....	.....	June 21–26	8.3
Oats-and-peas, 2 acres	4.0 3.0	April 2	June 26–July 4	12.4
Oats-and-peas, 2 acres	4.0 3.0	April 11	July 4–9	8.2
Alfalfa, 2d cutting	.....	.....	July 9–11	2.1
Oats-and-peas, 5 acres	10.0 7.5	April 19	July 11–22	16.4
Southern white corn, 2 acres	0.5	May 2	July 22–Aug. 3	17.7
Barnyard millet, 2 acres	1.4	June 19	Aug. 3–19	23.2
Soybeans, 1 acre	2.0	June 1	Aug. 19–25	8.8
Cowpeas, 1 acre	2.0	June 10	Aug. 25–Sept. 1	10.5
Cowpeas-and-kafir corn, 2 acres	2.0 1.0	July 10	Sept. 1–16	24.4
Pearl millet, 2 acres	0.25	July 11	Sept. 16–Oct. 1	20.2
Cowpeas, 1 acre	1.5	July 24	Oct. 1–5	8.0
Mixed grasses, 5 acres (partly dried)	.....	.....	Oct. 5–27	20.0
Barley, 2 acres	3.5	Sept. 2	Oct. 27–Nov. 1	5.2
Total	.....	.....	.....	278.3

III. The Preparation of Feeds

In the nomadic stage of husbandry the animals gathered their own food, the care of the owner ending when grazing, water, and protection from marauders were provided. With the change from primitive times the growing of plants and their conservation for animal use becomes an ever-increasing burden on the stockman. It is therefore a question of prime importance to determine to what extent such preparation of feeds as grinding or rolling grain, cutting or chaffing hay and coarse forage, and cooking various feeding stuffs is profitable.

The purpose of such artificial preparation of feed is to make it more digestible, to improve its palatability, or to permit the mixing of well-liked feeding stuffs with materials which would otherwise be refused. In studying any method of preparing feeds farmers must not only con-

sider the beneficial effect, if any, on the animals, but must also determine whether such effect is marked enough to warrant the added expense incurred. The value of the different practices for each class of stock is discussed in detail in the respective chapters of Part III, but a summary of the conclusions there drawn will be helpful in showing the principles which should govern the feeder in deciding how far to employ such methods of preparation.

423. Grinding, crushing, or rolling grain.—The value of grinding or crushing the various grains for the different classes of stock is discussed in detail in the respective chapters of Part III. However, the following brief summary will be helpful in pointing out some of the main facts concerning the profitableness of such preparation. As has been shown before (**83**), grinding, crushing, or rolling grain increases the digestibility only when animals fail to masticate the whole grain. For all animals, such grains as bald barley or rice, which are unusually hard, or small seeds, such as millet or weed seeds, should ordinarily be ground. For animals with poor teeth or for young animals before their teeth are well developed, grinding grain in general is advisable. Corn is not commonly ground for horses, and the saving thru crushing or grinding oats amounts to but 5 to 6 per ct. Such grains as barley and wheat should be crushed or ground for horses. (**463**) All grain should usually be ground for dairy cows. (**656**) Where pigs follow fattening cattle to gather up any grain which escapes mastication and digestion, there is no advantage in grinding corn or even shelling it, except perhaps toward the close of the feeding period, when the cattle may be induced to eat more by grinding. Where no pigs run with cattle, it is usually economical to grind or crush the corn before feeding. (**735-6**) The small grains should be ground for fattening cattle. (**730**) Except in the case of small or hard seeds, sheep with good teeth should grind their own grain. (**833**) While it pays to grind the small grains for pigs, there is no appreciable advantage in grinding corn for pigs weighing 150 lbs. or less. For older animals such preparation may sometimes be profitable. (**920-1**)

424. Cutting, chaffing or grinding forage.—Passing such coarse forages as corn or the sorghums thru a feed cutter or shredder is usually profitable, not because the portions consumed are digested more completely but because the animals waste less and the cut forage is more convenient to handle. This applies to soilage as well as cured forage. (**305**)

Whether or not it will pay to cut or grind hay will depend on the price of the hay, on its quality, and on the cost of preparation. When hay is cheap, there is little or no gain thru cutting or grinding hay of good quality which will be consumed with little waste. Such preparation is much more profitable with hay of poor quality, as the animals will consume the cut hay with much less waste. With hay at recent prices, many extensive feeders in the West have found it profitable to cut or grind alfalfa hay, even when of good quality, for fattening cattle and sheep. Trials show that chopping alfalfa hay of ordinary quality reasonably fine

may increase its value for fattening cattle and sheep 15 to 25 per ct.[33] (730, 834) Hay can be cut sufficiently fine for most purposes at low cost on the farm by means of a silage cutter equipped with an alfalfa screen. Cut hay and straw are often used in establishments where large numbers of horses are kept. (461) Little information is available concerning the saving thru cutting or grinding hay for dairy cows. As pointed out later, it is sometimes advantageous to cut legume hay for brood sows. (1016) The value of alfalfa meal has been previously discussed. (344)

425. Cooking feed.—In 1854 Professor Mapes voiced the popular opinion of those days when he wrote:[34] "Raw food is not in condition to be approximated to the tissues of animal life. The experiment often tried has proved that 18 or 19 lbs. of cooked corn are equal to 30 lbs. of raw corn for hog feed." Numerous careful trials have since shown, however, that, in general, cooking either grain or roughage does not increase its digestibility or nutritive value, but may even decrease the digestibility of the protein. For example, in trials by Ladd at the New York (Geneva) Station[35] the digestibility of the crude protein in uncooked corn meal was 68.6 per ct. and in the same corn meal after cooking only 60.5 per ct. The digestibility of the crude protein in clover hay and cottonseed meal was decreased similarly by cooking.

426. Steaming roughage for cattle.—Eighty years ago and even later, there could be found in this country establishments more or less elaborate used for steaming or boiling straw, corn stalks, hay, etc., for cattle feeding; it is doubtful if there is to-day a single one for this purpose. Feeding steamed hay to oxen at Poppelsdorf, Germany,[36] showed that steaming rendered the components of hay, especially the crude protein, less digestible. When dry hay was fed, 46 per ct. of the crude protein was digested, while in steamed hay only 30 per ct. was digested. The advice given years ago by the editor of an agricultural journal is as sound today as when given:[37] "The advantages are very slight and not worth the trouble of either building the fire, cutting the wood, or erecting the apparatus, to say nothing of all these combined, with danger and insurance added."

427. Cooking feed for swine.—While cooking feed for cattle was abandoned years ago, it is still practiced to some extent for swine. Fortunately the matter has been carefully studied by several experiment stations and definite conclusions reached. The most extended trial was one running 9 years at the Maine Agricultural College,[38] in which cooked and uncooked corn meal were fed. In each case there was a loss

[33]Potter and Withycombe, Oregon Sta., information to the authors; Morton, Colo. Bul. 187.

[34]Trans. Am. Inst., 1854, p. 373.

[35]N. Y. (Geneva) Rpt. 1885.

[36]Hornberger, Landw. Jahrb., 8, p. 933; Armsby, Manual of Cattle Feeding, p. 266.

[37]Country Gentleman, 1861, p. 112.

[38]Ann. Rpt. of Trustees of the Maine State Col. of Agr., 1878.

by cooking. It is not going too far to say that the investigators of this subject usually began their studies in the full belief that the common feeding stuffs would be improved by cooking. Yet the unmistakable results of their experiments showed them the error of their previous idea.

At the Wisconsin Station[39] the senior author, starting with the belief that cooking must increase the value of the common feeds for swine, after some 15 trials with cooked and uncooked whole corn, corn meal, ground barley, and wheat middlings, was forced to the conclusion that the Maine findings were correct. (922)

428. Stock bread.—In some sections of Europe bread is made from ground cereals, leguminous seeds, potatoes, cut straw, chaff, etc., principally for horses, tho sometimes for calves and cattle. The bread may be more appetizing than the original materials, but the chemical changes which take place as a whole do not increase its nutritive value. Such preparation can be generally recommended only where unpalatable feed may thereby be consumed with less waste. Unless baked into hard biscuits such bread will keep only a comparatively short time.

429. When cooking feed is advisable.—No one can review the large accumulation of data from the experiment stations without being convinced that, rather than there being a gain, there is in most cases an actual loss from cooking. The only exceptions are a few feeds, such as potatoes and field beans, which can be successfully fed to pigs only after being cooked. In winter it is often advantageous to give warm feed to pigs, but this is entirely different from cooking the feed.

430. Soaking feed.—When grain with hard or small kernels can not be conveniently ground or crushed, it should be softened by soaking before feeding, care being taken that the meal does not become stale by long standing. Old corn often becomes hard and flinty in the summer and sometimes causes sore mouths in cattle or other stock if fed whole. It should then be ground or soaked.

431. General conclusions.—It has generally been assumed that by grinding and cooking feed much labor is saved the animal, to the advantage of the feeder. This idea is based on the general theory that the less work the animal does in mastication and digestion the larger the net production of work, flesh, or milk. On the contrary, we know that the muscles of the body do not grow strong thru idleness, and that work and activity are conducive to bodily health, growth, and strength. We must therefore conclude that the organs of mastication and digestion should be kept working at their normal capacity.

The economy of the different methods of preparing feed for each class of stock is discussed in detail in the respective chapters of Part III.

[39] Wis. Rpt. 1893.

CHAPTER XVII

MANURIAL VALUE OF FEEDING STUFFS

Unless the plant food removed from the soil in crops is returned in some form, after a period of years reduced yields will tell the story of soil depletion. Already over great areas of our country the soil has been so "mined" of its original fertility that only by the liberal application of commercial fertilizers are remunerative crops now possible. This is shown by the fact that during 1920 there were sold in the United States about 7,000,000 tons of commercial fertilizers, worth about $250,000,000. In the South Atlantic states alone 3,824,000 tons were used in 1918, including hundreds of thousands of tons of cottonseed meal. Southern planters feed great quantities of cottonseed meal to their crops —a rational agriculture would combine mixed cropping and stock growing with cotton raising. The meal from the cotton seed would be fed to farm animals and the resulting manure, still rich in fertility, would pass back to the fields, thereby giving a double return.

A judicious use of commercial fertilizers is highly commendable, but their place in general agriculture is to supplement deficiencies only after all the fertility in feeding stuffs that have been fed to live stock has been wisely and fully conserved.

432. Farm manure as a fertilizer.—Just as with commercial fertilizers, the value of farm manure is computed on its content of nitrogen, phosphoric acid, and potash, for of the constituents which plants remove from the soil only these need ordinarily be replaced. Phosphoric acid and potash, when naturally lacking in the soil, or when they have been carried off in crops or animals sold, must be replaced by means of commercial fertilizers or the manure of farm animals. The nitrogen needed may be indirectly obtained from the air by raising legumes, but in practice much is purchased along with phosphoric acid and potash.

Not only do farm manures supply plant food, but the vegetable, or organic, matter they contain is important in increasing the productivity of the soil. As this vegetable matter gradually breaks down in the soil, the acid products formed help dissolve and make available to plants some of the otherwise insoluble plant food in the soil. Furthermore, the humus formed from the organic matter of manure helps retain moisture, improves the soil texture, renders it more resistant to wind action, etc. The value of organic matter to the soil is shown by the fact that on fields lacking in humus such crops as rye are often grown and turned under as green manure for the sole purpose of increasing the humus content.

Farm manures teem with bacteria of various kinds which cause chemical changes not only in the manure but also in the soil itself, converting insoluble plant food into forms available for crop growth.

After much practical work at the Ohio Station, Thorne[1] concludes that the fertilizing constituents of farm manures have as high a value per pound as those in such high-grade fertilizers as tankage, bone meal, and muriate of potash. In view of the highly beneficial effects which farm manure has in addition to supplying nitrogen, phosphoric acid, and potash, this is a conservative estimate. Previous to the World War the price of the fertilizing constituents in commercial fertilizers was about as follows: nitrogen 18, phosphoric acid 4.5, and potash 5 cents per pound. Tho the prices of fertilizers have now declined materially from war-time levels, at present the fertilizing constituents can not be secured at retail in high-grade fertilizers for less than approximately the following amounts: nitrogen 20, phosphoric acid 7, and potash 7 cents per pound. These values are accordingly used in this volume in computing the fertilizing value of feeding stuffs and the manure resulting from feeding them to farm animals.

433. Fertilizing constituents recovered in manure.—The proportion which is recovered in the manure of the total nitrogen, phosphoric acid, and potash supplied in the feed depends on the age and kind of animal, as shown in the following table from Warington:[2]

Proportion of nitrogen and ash of food which is voided by animal

	Nitrogen Per ct.	Ash Per ct.
Horse at work	100.0	100.0
Fattening ox	96.1	97.7
Fattening sheep	95.7	96.2
Fattening pig	85.3	96.0
Milk cow	75.5	89.7
Calf, fed milk	30.7	45.7

The mature horse at work is merely repairing his body tissues as they are broken down. (**140**) Therefore no nitrogen or ash (containing the phosphoric acid and potash) is stored in his body, but all the nitrogen and practically all of the ash are voided in the manure. (A negligible amount of ash is excreted in the perspiration.) With fattening animals whose bodies are nearly or quite mature, but little of the fertilizing constituents supplied in the food are retained in the body, over 95 per ct. of both nitrogen and ash being voided by the fattening ox and sheep. (**123**) With the pig fattened while not yet mature and storing nitrogen in his lean-meat tissues, about 85 per ct. of the nitrogen of the food is returned in the manure. As milk is rich in nitrogen and ash, the cow in milk voids only about 75 per ct. of the nitrogen and 89 per ct. of the ash contained in her food. (**149**) The young calf, growing rapidly in bone, muscle, and body organs, voids only 30.7 per ct. of the

[1] Ohio Bul. 183.

[2] Chemistry of the Farm, p. 214.

nitrogen and 45.7 per ct. of the ash in the food, storing the balance in its body. (113) Considering the proportion of young animals and of those giving milk on the average farm, it has been estimated[3] that from the feed supplied farm stock about 80 per ct. of the nitrogen, phosphoric acid, and potash is ordinarily recovered in the feces and urine. The proportion of the organic matter of the food which is found in the feces will vary widely, depending on the proportion of difficultly digestible roughage in the ration. For well-fed ruminants and horses it ranges from about 20 to 35 per ct. As has been indicated before (432), the organic matter is a highly important factor in the beneficial action of the manure. No definite money value is, however, usually given to it in discussions of the fertilizing value of farm manures.

434. Influence of feed on the value of manure.—The animal creates nothing of fertilizing value, for it voids only that which it has eaten or drunk. Part of the fertilizing constituents is retained for the formation of flesh or milk, and the rest is voided in the excrements. The value of manure therefore depends primarily on the character of the food consumed. Foods rich in nitrogen, phosphoric acid, and potash yield rich manure; those low in these constituents make poor manure. For example, in a trial reported by Warington,[4] cows fed alfalfa hay voided daily in their urine over twice as much nitrogen as did cows which were fed only mangels.

435. Fertility and manurial value of feeds.—Since the value of manure depends primarily on the amounts of nitrogen, phosphoric acid, and potash in the feed eaten, it is important to consider the amounts and value of these fertilizing constituents in typical feeds and animal products, as shown in the following table. These are taken from the extensive data in Appendix Table III. The fertility value of each feed per ton, shown in this table, has been computed on the basis of what the total nitrogen, phosphoric acid and potash in that feed would cost if purchased in commercial fertilizers. The last column gives the manurial value[5] of each feed; i.e., the value of the manure which would result from feeding 1 ton of the feed to live stock. This has been computed on the assumption that, on the average, farm animals return in the manure about 80 per ct. of the total fertilizing value of the feed, but that even under good management some losses occur in the nitrogen of the manure which reduce the amount of this constituent in the manure to 65 per ct. of the amount in the feed. Obviously, these manurial values hold good only when the manure is so cared for as to prevent as much as possible the losses mentioned later. Farm manure is relatively rich in nitrogen compared with phosphoric acid. On farms where much live stock is kept and legumes are grown in rotation to help furnish nitrogen, if farm manure only is used as fertilizer many types of soil will become unduly rich in nitrogen compared with phosphoric acid. Under such conditions the full

[3] Van Slyke, Fertilizers and Crops, 1912, p. 300.

[4] Chemistry of the Farm, p. 218.

[5] Hart, Wis. Bul. 221.

manurial values can be obtained only when the manure is supplemented with a fertilizer supplying phosphoric acid.

Fertilizing constituents in feeding stuffs and animal products

	Fertilizing constituents in 1,000 lbs.			Fertility value per ton	Manurial value per ton
	Nitrogen	Phosphoric acid	Potash		
	Lbs.	Lbs.	Lbs.	Dollars	Dollars
Concentrates					
Dent corn	16.2	6.9	4.0	8.00	5.43
Oats	19.8	8.1	5.6	9.84	6.68
Wheat	19.8	8.6	5.3	9.87	6.71
Wheat bran	25.6	29.5	16.2	16.64	11.78
Linseed meal, old process	54.2	17.0	12.7	25.84	17.42
Cottonseed meal, choice	70.6	26.7	18.1	34.51	23.37
Tankage, high-grade	96.6	55.8	5.5	47.22	31.98
Roughages					
Timothy hay	9.9	3.1	13.6	6.29	4.44
Red clover hay	20.5	3.9	16.3	11.03	7.59
Alfalfa hay	23.8	5.4	22.3	13.40	9.29
Oat straw	5.8	2.1	15.0	4.71	3.43
Corn silage, recent analyses	3.4	1.6	4.4	2.20	1.55
Animals and animal products					
Fat ox	23.3	15.5	1.8	11.74	.....
Fat pig	17.7	6.5	1.4	8.19	.....
Milk	5.8	1.9	1.7	2.82	1.91
Butter	1.2	0.4	0.4	.59	.40

The fertility values given in the fourth column mean, for example, that the nitrogen, phosphoric acid, and potash removed from the soil in a ton of oat straw will cost not less than $4.71 if bought in the market in commercial fertilizers. A ton of corn (grain) removes $8.00 in fertility, and of wheat, $9.87. Because the legumes usually obtain much of their nitrogen from the air, only a part of the fertility in a ton of clover hay, worth $11.03, may have been taken from the soil. Clover hay is 75 per ct. richer than timothy hay and about 2.3 times as rich as oat straw in fertility. The fertility value of wheat bran is $16.64 per ton, while that of the wheat grain is only $9.87.

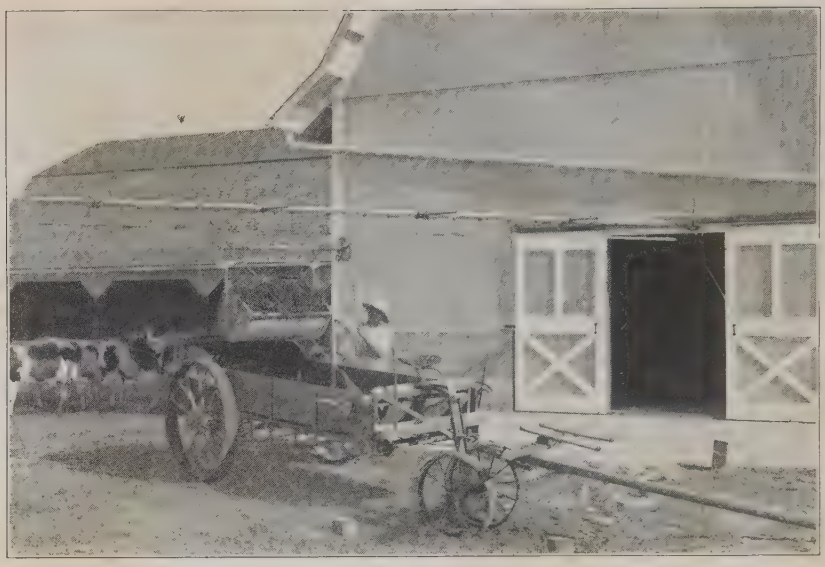
Of the feeds listed, tankage has the highest fertility value, $47.22 per ton, and cottonseed meal comes next, with a fertility value of $34.51 per ton. This explains why these materials, which are such valuable feeds, are often applied directly to the land as fertilizer. Indeed, in 1918 about 35 per ct. of the cottonseed meal and 57 per ct. of the high-grade tankage sold in this country was used as fertilizer. Where such protein-rich feeds as cottonseed meal are purchased and fed to live stock on the farm and the manure produced is properly cared for and applied, a double return will be realized—a return not only from the feeding value, but also from the manurial value. The manure resulting from each ton of cottonseed meal fed will be worth $23.37, the manurial

SUCH LOSSES OF FERTILITY OCCUR ON MANY FARMS

When manure is loosely piled under the eaves, heavy losses of fertility occur thru fermentation and leaching. Note that every hard rain will leach fertility from the manure pile to the ditch in the foreground. (From Wisconsin Station.)

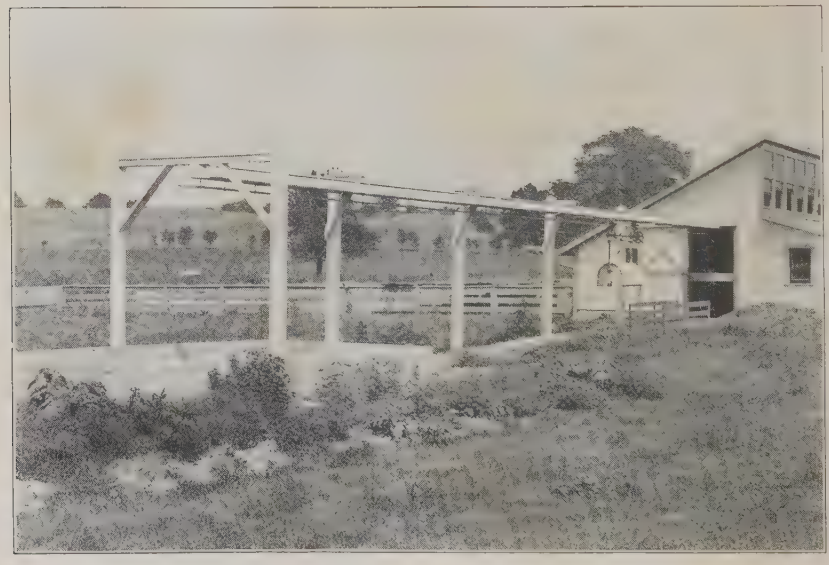
THE RESULT OF ALLOWING MANURE TO WASTE AWAY

When manure is allowed to waste away as in the preceding illustration, not only is much of the weight of the manure lost, but that which remains contains much less fertility per ton than fresh manure. The pile of corn at the left was grown on a plot fertilized with manure which had been exposed to the weather over winter. The large pile at the right was grown on a plot fertilized with the same amount of fresh manure. (From Wisconsin Station.)



Saving the Fertility in Feeding Stuffs

If possible, the manure should be drawn directly to the fields and spread each day. However, this is not advisable on sloping land in winter when there is deep snow on the fields.



A Cheap but Efficient Manure Pit

When manure is piled solidly in a pit like this with concrete walls and floor, there is but little loss from fermentation and none from leaching.

value, as surely as would the application to the same land of mixed commercial fertilizers worth this amount.

436. Selling fertility.—The table in the preceding article further shows that those who sell such crops as hay, corn, and wheat part with far more fertility for a given sum of money than do those who sell animals or their products. The farmer who sells 1,000 lbs. of clover hay, worth $6 to $10, parts with about as much fertility as if he had sold 1,000 lbs. of fat steer or pig, worth $70 to $100, or more. Based on the selling price, milk carries considerable fertility from the farm, and butter practically none. Farm crops may be regarded as raw products, while farm animals, milk, wool, butter, etc., represent manufactured products. A large amount of raw material in the form of grass, hay, corn, etc., is put into animals, and the heavy waste or by-product resulting, in the form of manure, when carried back to the fields conserves most of the fertility. The farmer who feeds his crops to live stock is a manufacturer as well as a producer, with two possible profits instead of one, while his farm loses little of its fertility. The farmer who grows and sells grain, hay, and straw is selling a large amount of fertility, the need of which will surely be apparent as time goes on and his fields give smaller and smaller returns. Such a farmer is slowly but surely mining phosphorus and potash from his soil, which can be replaced only by some purchased material.

Virgin soils as a rule contain great quantities of available fertility, and the pioneer farmers in America, drawing upon Nature's store, have given little consideration to how their crops are fed and have not realized that they are steadily and often wastefully drawing on the store of fertility which represents their principal capital. The western farmer, when marketing corn or wheat, or the southern planter, when selling seed cotton, considers he is selling labor and rent of land. Rarely does he realize that he is also selling fertility, to replace which would cost a considerable part of all the crop brings. Rather than to reckon the value of his crop at the market price, he should recognize that its true value when sold from the farm is really the market price minus the value of the fertility which the crop removes from the soil.

437. Buying fertility in purchased feeds.—Even in live stock farming where little or no grain or roughage is sold and when proper care is taken of the manure, not all of the fertility removed in the crops is returned in the manure. The growth of legumes will aid in maintaining the nitrogen supply in the soil, but under actual conditions on most farms, supplying additional nitrogen in manure or fertilizer will increase crop yields. Sooner or later in practically all cases it is necessary to replace the small but steady loss of phosphoric acid and potash, even when most of the crops are fed to stock and the manure is handled properly. Therefore, in purchasing feeding stuffs, one should always consider not only their feeding value but also their worth as fertilizers. By a wise selection of purchased concentrates the live stock farmer can build up the fertility

of his farm without the use of any commercial fertilizers, except lime to correct soil acidity and perhaps phosphate to balance the farm manure, which is ordinarily much richer in nitrogen than in phosphoric acid.

In purchasing feeds one should always consider their manurial value as well as their feeding value, in determining which are really the most economical to buy. From the actual cost or value per ton there should be deducted the manurial value per ton computed on the basis given in Article 435, and taking the current prices for nitrogen, phosphoric acid, and potash. To illustrate this method of comparing the actual relative economy of various concentrates, the following table is presented. The gross price per ton given for each feed is the same as was assumed for the corn-belt dairyman in Chapter VIII. (193)

Comparing cost of concentrates, after crediting manurial values

	Actual gross price per ton Dollars	Manurial value per ton Dollars	Net cost per ton Dollars	Net cost per pound total dig. nutrients Cents
Dent corn, ground	22.00	5.43	16.57	0.97
Oats, ground	23.88	6.68	17.20	1.22
Hominy feed	25.00	6.87	18.13	1.07
Corn-and-oat feed	24.00	5.38	18.62	1.23
Wheat bran	25.00	11.78	13.22	1.08
Gluten feed	30.00	11.51	18.49	1.46
Cottonseed meal, choice	35.00	23.37	11.63	0.74
Linseed meal, old process	35.00	17.42	17.58	1.13

The table shows clearly that for this corn-belt dairyman the actual gross price of the carbonaceous feeds—corn, oats, hominy feed, and corn-and-oat feed—was less per ton than the actual gross price of the protein-rich concentrates. But when credit is given, as should generally be, for the manurial value of the different feeds, the net cost per ton for cottonseed meal and wheat bran is actually lower than for the farm grown grains. Where proper use is made of the farm manure, the net cost per pound of total digestible nutrients is only 0.74 cent in cottonseed meal, while it is 0.97 cent in dent corn and 1.22 cents in oats. Thus without considering their value as protein-rich supplements to balance the farm grown feeds, but taking into account merely their manurial value, such feeds as cottonseed meal are cheap. Under such conditions they are far from being "high-priced purchased feeds," as they are often termed by those who do not realize the importance of the fertilizing constituents they return to the land.

438. British practice.—In Great Britain, where many of the farmers are long-period tenants, the manurial value of feeding stuffs is recognized by law in a manner that tends greatly to the betterment and permanence of her agriculture. The Agricultural Holdings Act, which is the law governing the relations between landlord and tenant, directs that when a tenant is vacating his leasehold he shall be reasonably compensated for the improvements he has made. Among these, credit must be given for the fertilizing value of feeding stuffs which the tenant may have

purchased and fed out, and also, under certain conditions, for the fertilizing value of grains produced on the farm and fed to stock. In order to furnish data to guide the valuers who serve in settlement between landlord and tenant, after full and extended study Lawes and Gilbert and later Voelcker and Hall of the Rothamsted Experiment Station drew up tables showing the compensation to be allowed for the fertilizing value of various feeds. The recommendations, as revised in 1913 and adopted by the Central Association of Agriculture and Tenant Right Valuers,[7] are that the tenant shall be credited as follows for all manure resulting from feeding purchased feeds to stock on the leasehold:

For all unused manure or that which has been recently applied to the land without a crop being grown thereafter, a credit of three-fourths of the total value of the phosphoric acid and potash in the feed is allowed. Because a greater loss of nitrogen commonly occurs in stored manure than in manure dropped in the fields by animals at pasture, a credit of 70 per ct. of the total value of the nitrogen is allowed when the stock have been fed at pasture, and of only 50 per ct. when they have been fed in barn or yard.

When one crop has been grown since the application of the manure, a part of the fertility thereby being used up, the credit allowed is only half that stated above. It is realized that the beneficial effects of farm manure persist much longer than 2 years, but owing to the difficulties of checking records for a longer period, the compensation is not extended over a greater time. The principles of the English law, as here set forth, should be drafted into every lease drawn between landlord and tenant in this country.

439. Composition and value of fresh manure.—Even tho the value of manure produced by animals of the same kind depends primarily on the nature of the feed supplied, it is important to note the approximate composition of manure from the different classes of farm animals. The following table, adapted from Van Slyke,[8] shows the percentage of water and the amount and value of the fertilizing constituents per ton in fresh manure, including feces, urine and bedding, from the different farm animals.

Composition of one ton of average manure from farm animals

	Water Per ct.	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Value Dollars
Horse manure	78	14	5	11	3.92
Cow manure	86	12	3	9	3.24
Sheep manure	68	19	7	20	5.69
Pig manure	87	10	7	8	3.05

Horse and sheep manures contain less water than that of cows or pigs, and are known as "hot manures" because their low water content

[7] Journ. Roy. Agr. Soc., England, 74, 1913, pp. 104-119.

[8] Fertilizers and Crops, p. 291.

permits rapid fermentation when stored. On the other hand the voidings of the cow and pig form "cold manures," the high water content checking fermentation. Sheep manure has the highest value per ton, based on fertilizing constituents; pig manure the lowest. Mixed farm manure, including bedding, carries about 10 lbs. of nitrogen, 5 lbs. of phosphoric acid, and 10 lbs. of potash per ton, and is therefore worth about $3.05 a ton.

440. Amount of manure voided.—Various methods have been suggested for computing the amount of fresh manure—feces and urine—produced by farm animals. Heiden[9] found that 100 lbs. of dry matter fed to farm animals produced the amount of fresh manure shown in the first column of the following table. The second column gives the weight of manure plus bedding, computed from data by Van Slyke.[10]

Manure from 100 lbs. dry matter fed to farm animals

	Manure Lbs.	Manure plus bedding Lbs.
Horse	210	280
Cow	384	427
Sheep	183	285

Owing to the high water content of cow manure, a larger amount is produced from 100 lbs. of dry matter in the feed than in the case of the horse or sheep.

The amount of manure voided daily by farm animals varies widely, depending on the nature and amount of feed given and the age, activity, etc. of the animals. The following table, adapted from Van Slyke,[11] is a helpful approximation of the amount of manure voided daily by farm animals, per 1,000 lbs. live weight.

Daily production of manure by farm animals per 1,000 lbs. live weight

	Feces Lbs.	Urine Lbs.	Total manure Lbs.	Manure plus bedding Lbs.
Horse	39	10	49	65
Cow	52	22	74	82
Sheep	23	11	34	53
Pig	50	33	83	99

Based on live weight, the pig yields more manure than other farm animals, due to the heavy feed consumption per 1,000 lbs. live weight and the watery nature of the manure.

441. Fertilizing constituents produced yearly.—According to Van Slyke,[12] the amounts of fertilizing constituents voided annually by farm animals per 1,000 lbs. live weight are about as follows:

[9] Storer, Agriculture, 1899, II, p. 289.
[10] Fertilizers and Crops, p. 303.
[11] Fertilizers and Crops, pp. 294, 303.
[12] Fertilizers and Crops, p. 295.

Annual yield of fertilizing constituents per 1,000 lbs. live weight

	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Value of manure Dollars
Horse	128	43	103	30.70
Cow	156	38	127	36.51
Sheep	119	44	126	30.94
Pig	150	104	128	40.24

The last column shows the total value of the manure produced annually, computed at the prices previously given, and assuming that 20 per ct. of the nitrogen is unavoidably lost. (**432**)

442. Losses in farm manures.*—From the foregoing it is evident that farm manure is one of the most valuable products of the farm. Yet many farmers who freely purchase commercial fertilizers allow much of the value of the manure produced by their live stock to be washed away in streams or otherwise dissipated. It is most important to realize that manure is a perishable product, and that unless proper care is taken over half its value may be lost. Plant food may be wasted thru: (1) Loss of urine, (2) loss by leaching, (3) loss of nitrogen by fermentation.

The importance of bedding to absorb the urine is shown in the following table from Van Slyke:[13]

Proportion of fertilizing constituents in urine and feces of farm animals

	Nitrogen in		Phosphoric acid in		Potash in	
	Urine Per ct.	Feces Per ct.	Urine Per ct.	Feces Per ct.	Urine Per ct.	Feces Per ct.
Horse	38	62	0	100	44	56
Cow	51	49	0	100	85	15
Sheep	48	52	5	95	70	30
Pig	33	67	12	88	43	57
Average	43	57	4	96	60	40

With the cow and sheep about half the nitrogen is voided in the urine; with the horse and pig somewhat less. Most of the phosphoric acid is excreted in the feces. The cow voids about 85 per ct. and the sheep 70 per ct. of the potash in the urine; the horse and pig over 40 per ct. For all farm animals, 43 per ct. of the nitrogen and 60 per ct. of the potash passes in the urine. Pound for pound, the urine has a greater fertilizing value than the feces, except with the pig. The fertility in urine is also in solution and hence much more readily available to plants than that in the feces.

A manure pile under the eaves, against the side of the barn, or manure lying for months in an open barn yard is a sight all too common on American farms. When manure is exposed to the leaching action of the rains, the losses are great, even amounting to half of the total

[13] Fertilizers and Crops, p. 295.

*This discussion of the losses in manure and the care of this valuable farm product is necessarily very brief. For more complete information consult the standard works on Soils and Agricultural Chemistry.

value in periods of 2 to 5 months. Obviously, the loss falls on the constituents which are most soluble and most quickly available to plants.

Farm manure is teeming with bacteria, molds, and yeasts, the numbers often running into billions for each gram of manure. These organisms in general break down the complex compounds of the manure into simpler ones, which are soluble. Some of these changes are advantageous, as they make the plant food more available to crops, but under improper conditions of storage much of the nitrogen in the manure may be lost thru these fermentations. When the manure is dry or loosely packed, the bacteria which thrive in the presence of air develop profusely, causing "hot" fermentation. In this process there is a rapid formation of ammonia, much of which passes as gas into the air. The strong smell which every farmer has noticed in close horse stables is due to this escaping ammonia gas produced by the breaking down of nitrogen compounds in the urine. In still other changes which may take place free nitrogen gas may be formed, which is likewise lost into the air. When the pile of manure is well packed and is kept damp, these changes can not go on, but only the beneficial decompositions which render the plant food more available and produce what is termed "well-rotted manure." If the manure is very loose and dry, "fire fanging," may occur, when the manure becomes grayish or dusty in appearance. This change, produced by certain fungi, seriously injures the manure. Phosphoric acid and potash are not lost thru fermentation, but heavy losses may occur thru leaching.

443. Care of manure.—To prevent loss in manure, the urine should be saved by having tight gutters and using plenty of bedding. If possible, the manure should be drawn directly to the fields and spread each day. This is not advisable, however, in winter on very sloping land when covered by deep snow, as much fertility may wash down the hill in the spring. When manure can not be spread on the land, it should be stored, preferably in well-packed piles kept moist to prevent hot fermentation, and preferably under cover or in a manure pit. If hogs or cattle have access to the shed, they aid in firming the pile. It is an excellent plan to mix the manure from horses or sheep, which is drier and therefore called "hot manure," with that from cattle or pigs, which contains more water. In Europe manure is often stored in pits and cisterns. When it is necessary to leave manure out of doors, the pile should be made high and compact, so that rains will not soak thru, and should be built with the sides perpendicular and the top sloping toward the center so that all rain will soak into the pile instead of draining off as from a stack of hay. It is impossible to prevent all waste in caring for manure, but under proper management not over 10 to 20 per ct. of the nitrogen and practically none of the phosphoric acid and potash will be lost.

Part III

FEEDING FARM ANIMALS

CHAPTER XVIII

FACTORS INFLUENCING THE WORK OF THE HORSE

In spite of the coming of the tractor and the auto-truck, the number of horses on farms in the United States decreased only from 19,833,113 in 1910 to 19,099,000 in 1922, and the number of mules rose from 4,209,769 in 1910, to 5,436,000 in 1922.[1] Thus the 29.1 per ct. increase in the number of mules during the 12 years more than offset the decrease in the number of horses on farms. While tractors and trucks have a place on farms of sufficient size to render their operation economical, it is evident from these figures that mechanical power will supplement rather than largely displace horses on our farms. Some of the various factors which a farmer should consider in determing whether or not he should purchase a tractor are discussed later in this chapter.

During the past decade the number of horses used in cities decreased from 3,182,789 to 1,705,611, due to the general displacement of driving horses by automobiles and a wide-spread substitution of auto trucks for draft horses. Without question, the nearly complete elimination of the driving horse in the cities will be permanent. However, it is quite probable that in the future there will be an increase rather than a decrease in the number of draft horses used in cities for the shorter hauls in delivery and trucking service. This is due to the fact, recently called to public attention by Dinsmore of the Horse Association of America, that under many conditions horses are more economical than trucks for such service. Furthermore, while trucks may be out of service for repairs or in inclement winter weather, horses can be depended on the year around.

Many people fail to appreciate the magnitude of our horse and mule industry. On January 1, 1922, the estimated total value of the horses and mules on farms in this country was over $1,800,000,000, a sum considerably greater than that of any other class of farm stock. To feed and care for these work animals means an annual expense of about $2,000,000. In spite of the magnitude of the industry, less attention is given to the economical feeding of this class of live stock than to any other farm animals. Many a farmer, for instance, will carefully determine which of the feeds available for his dairy herd will furnish a well-balanced ration

[1] U. S. Dept. Agr., *Weather, Crops, and Markets*, Feb. 25, 1922.

most cheaply. Yet he may forget that similar principles apply to the feeding of his work animals. An average of about 4 horses or mules are kept on each farm in the United States. When we learn in Chapter XIX how it is often possible thru the economical and proper selection of feeds and their rational administration to save 10 to 40 per ct. of the usual feed bill, with no injury, and in some cases even a benefit to the animals, it is evident that a careful consideration of the principles governing the feeding of horses will pay every owner in dollars and cents. Furthermore, it is just as essential to care for work animals so as to ensure their maximum efficiency as it is to lubricate carefully the vehicles and machinery they draw.

Before studying in detail the feeds for the horse and the methods of feeding and care, it is necessary to consider briefly the principles determining the value of the different classes of feeds for the production of work and the various factors which influence the amount of labor the animal can perform.

Most of the discussions which follow treat of the horse particularly, since about 78 per ct. of our work animals are horses, and nearly all of the scientific trials have been conducted with them. The same feeds may be used for mules, however, and the same principles of feeding and care apply to these animals. (Special hints on the feed and care of the mule are given in Art. 532.)

I. Factors Influencing the Work Done by Horses

444. Work done by horses.—In measuring work, the units are the foot-pound and the foot-ton. A *foot-pound* is the work done in lifting one pound one foot against the force of gravity; and a *foot-ton* the amount done in lifting one ton one foot against gravity. The rate at which work is performed is measured in terms of horse-power. A *horse-power* is the power required to lift 33,000 lbs. at the rate of 1 ft. per minute, or to lift 1 lb. at the rate of 33,000 ft. per minute. To illustrate, a horse drawing up a loaded bucket weighing 100 lbs. from a well 330 feet deep in one minute exerts a force equal to 1 horse-power.

The work which horses can do depends on their weight, muscular development, and endurance. At steady and continuous work for 10 hours a day, the pull or draft for a horse should not be more than one-eighth to one-tenth its weight. The daily work performed by horses of different weights would then be about as follows[2]:

Daily work performed by horses of different weights

	Horse-power produced	Foot-tons of work done
800-lb. horse	0.53—0.67	5,247— 6,633
1000-lb. horse	0.67—0.83	6,633— 8,217
1200-lb. horse	0.80—1.00	7,920— 9,900
1400-lb. horse	0.93—1.17	9,207—11,583
1600-lb. horse	1.06—1.33	10,494—13,167

[2] King, Physics of Agr., p. 490.

WELL-BRED DRAFT HORSES PERFORM WORK EFFICIENTLY

The conformation of the draft horse, developed by years of breeding, fits him to haul heavy loads efficiently at a relatively slow speed. (From Horse Association of America.)

SPEED DECREASES THE WORK THAT CAN BE PERFORMED

A pound of additional load makes but little difference to a draft horse, but with the race horse the load must be made as light as possible. (From *The Horseman.*)

REDUCING THE COST OF HORSE LABOR BY RAISING FOALS

A team of such brood mares would bring added profits to many farms where no foals are now raised. They will not only produce profitable foals, but will also do no small part of the farm work. (From Illinois Station.)

HORSES AND MULES COMPETE SUCCESSFULLY WITH TRACTORS

Under present conditions, tractors will only supplement, rather than replace horse or mule labor on most farms. With feed low in price, the horse or mule performs draft more cheaply than the tractor.

For a short time a horse can exert a pull of about one-half its weight. The ox draws a load equal to the horse, but ordinarily at only two-thirds the speed. A man's work is usually from one-sixth to one-tenth of a horse power, or about one-fifth that of an average horse. For a minute or two he can exert a full horse power or even more.

The character of the road bed is a most important factor in determining how heavy a load a horse can draw. The following table shows the draft required per ton of load, including the weight of the wagon, to haul a 4-wheeled wagon on various types of level road.[3]

Draft required to haul a wagon on various types of road

Character of road	Draft per ton Lbs.	Character of road	Draft per ton Lbs.
Wood block, good	33	Vitrified brick	55
Sheet asphalt, good	38	Oiled road, dry	61
Macadam, average	46	Earth, packed and dry	100
Gravel, good	51	Earth, muddy	190
Cobblestone	54	Sand, loose	320

The table shows that it requires a draft, or pull, of only about 33 lbs., as measured by a dynamometer, a crude form of which is a spring balance placed between horse and load, to draw a load of a ton, including wagon, on a good wood block road and of 38 lbs. on a sheet asphalt roadway. On poor roads the draft is many times greater, being 190 lbs. on a muddy earth road and 320 lbs. on loose sand.

445. Digestion trials.—Since there have been relatively few digestion trials with the horse, we are usually obliged to use for this animal the coefficients of digestibility obtained with the ox or sheep. (**66**) While the horse digests the easily digested feeds about as completely as do the ruminants, it falls below them in ability to digest the more difficultly digested ones. This is shown by the digestion coefficients for typical feeds given in Appendix Table II of this book. The horse digests 88 per ct. of the dry matter in corn and ruminants 90 per ct. On the other hand, the horse digests only 44 per ct. of the dry matter of timothy hay, while ruminants digest 58 per ct. (**85**)

446. Influence of work on digestibility.—The effect of working a horse immediately after eating has been studied by Grandeau and LeClerc,[4] Tangl,[5] Colin,[6] Scheunert[7] and others. Their investigations show that moderate exercise, even immediately after the horse has eaten, tends to increase digestion in both the stomach and the small intestine, and also increases the rate of absorption of digested nutrients. Tho the rate of protein digestion is retarded for the first hour after eating, when the horse is exercised immediately after the meal, by the end of the second

[3] Agg, Construction of Roads and Pavements, p. 343.
[4] Ann. Sci. Agron., 1884, Vol. II, p. 235.
[5] Pflüger's Arch. Physiol., 63, 1896, p. 545.
[6] Traite Physiol. Comp. Anim., 1886, p. 822.
[7] Pflüger's Arch. Physiol., 109, 1905, p. 145-198.

or third hour even more protein will have been digested than had the horse remained at rest. Contrary to some statements, exercise does not hasten the passage of food from the stomach into the small intestine, but apparently retards it. Severe labor may, however, depress digestion. Grandeau and LeClerc found that hard work at a trot lowered the digestibility of the protein 7 per ct. and of the fiber 13 per ct., compared with the amounts digested when the horse was allowed to rest after eating. The greater depression observed in the case of the crude fiber is doubtless due to the fact that this nutrient is digested mainly in the caecum and large intestine and is hurried thru these organs by the motion of the horse in action.

447. True value of feeds for work.—As previously shown (**78-80**), the true value of different feeds for work is not based merely on the amount of digestible nutrients they contain, for a varying percentage of the available energy in the digestible portion of the feed is used up in the work of mastication and digestion, and thereby lost so far as useful mechanical work is concerned. By subtracting the energy thus used from the available energy which the digestible nutrients of any feed furnish, we will find the amount of net nutrients which may be used in the performance of such external work as propelling the body, carrying a burden, or pulling a load. We should remember, however, that the energy which is used up in mastication and digestion is all changed into heat, and so may aid in keeping the body warm.

It has been pointed out in a previous chapter that the net energy values for various classes of animals differ to a greater or less extent and that in most of the experiments carried on to determine the net energy value of feeds, fattening steers have been used. (**177**) Armsby[8] has recently computed the net energy values for a few feeds when fed to the horse, using the results of Zuntz and Hagemann[9] and the analyses and the digestion coefficients given in Appendix Tables I and II of this book. These are given in the table on the next page.

It will be noted that these net energy values differ quite widely from those for ruminants. (**171**) For example, the net energy value of dent corn for ruminants is given as 89.16 therms and for horses, 112.80 therms per 100 lbs. The net energy value of alfalfa hay for ruminants is reported as considerably lower than that of timothy hay. On the other hand, in this table the net energy value of alfalfa hay for horses is given as nearly double that of timothy hay. These values should be regarded as merely approximations, showing the relative value of typical feeds for the production of work. The table shows a negative net energy value for wheat straw of —20.90 therms per 100 lbs. This means that the work of masticating, digesting, and assimilating wheat straw uses up more energy than the straw furnishes. This feed therefore is worse than worthless for feeding a hard-worked horse. However, straw is of value for maintaining

[8] Nutrition of Farm Animals, 1917, p. 721.

[9] Landw. Jahrb., 27, 1898, Sup. III, p. 431.

idle horses and may be used advantageously for this purpose along with other feed. With idle animals the chief need is not for net energy but for heat to maintain the body temperature. As has been shown before (**80**), the energy used up in mastication, digestion, and assimilation all takes the form of heat and thus aids in warming the body.

Net energy values of feeds per 100 lbs. for horses

	Dry matter	Digestible crude protein	Digestible true protein	Net energy
	Lbs.	Lbs.	Lbs.	Therms
Corn, dent	89.5	5.9	5.4	112.80
Oats	90.8	9.9	8.9	93.44
Horse bean	87.4	19.5	17.1	109.40
Peas	90.8	18.7	16.3	105.20
Linseed cake	90.9	29.5	27.8	101.60
Timothy hay	88.4	1.3	0.5	26.64
Alfalfa hay	91.4	10.9	7.4	48.82
Red clover hay	87.1	7.2	4.5	39.94
Wheat straw	91.6	0.8	0.4	-20.90
Carrots	11.7	1.2	0.8	16.60
Potatoes	21.2	1.9	0.9	35.70

These net energy values, given in the preceding table, should be used instead of the net energy values for ruminants given in Chapter VI (**171**), when it is desired to compute rations for horses by the Armsby standard. (**174**) For most feeds it will be necessary to use the net energy values for ruminants, since none are available for horses.

448. Maintenance requirements of the horse.—It is more difficult to determine the minimum amount of nutrients needed to maintain the weight of a horse than of the ox or sheep. This is due to the fact that any excess of nutrients supplied the idle horse above maintenance will not usually be wholly stored as flesh or fat, for confined horses, even those of quiet temperament, dissipate more or less energy thru restlessness and moving about, so that a ration which barely maintains them is really somewhat in excess of the theoretical requirement.

By feeding horses at first rations which were insufficient to maintain their weights, and then gradually increasing the amount of feed until the live weights were barely maintained, Grandeau and LeClerc[10] were able to maintain horses on a ration of meadow hay which furnished 7 lbs. of digestible nutrients, or 13.1 therms of available energy, per 1,000 lbs. live weight. Using another method Zuntz and his colleagues[11] found that for maintenance the horse needed 6.4 lbs. digestible nutrients, or 11.9 therms of available energy per 1,000 lbs. live weight. It was found that the larger part of the nutrients, nearly 66 per ct., were required merely as fuel to maintain the temperature of the body. Indeed, it was necessary to supply only 2.43 lbs. of net nutrients (or 4.1 therms of net energy) to

[10]London Live Stock Jour., 1894, p. 9.

[11]Land. Jahrb., 27, 1898, Sup. III, pp. 422-426.

cover the amount used up in the internal work of the body and in repairing the body tissues.

This conclusion accords with the general experience, that idle horses can be maintained chiefly on such feeds as hay, corn stover, and straw, which furnish relatively little net energy but produce a large amount of heat in the body as the result of mastication and digestion. If the roughages are of sufficiently good quality, the animals may be maintained on such feeds alone. As roughages are usually far cheaper sources of total available energy than the concentrates, maintaining idle horses on such feeds is obviously economical.

In addition to supplying sufficient fuel to maintain the body temperature and enough net nutrients for the internal work of the body, as has been previously pointed out (**93**), the nutrients in the ration must include a certain amount of digestible protein to make good the small daily waste of nitrogenous tissues. In experiments by Grandeau and LeClerc, horses were maintained for periods of 4 to 5 months on rations of meadow hay which furnished an average of only 0.54 lb. digestible protein daily per 1,000 lbs. live weight. Most authorities maintain, and practical experience shows, that the health of animals is improved when they are fed more than the theoretical minimum of protein. In view of this, in the Morrison feeding standard 0.8 to 1.0 lb. of digestible crude protein per 1,000 lbs. live weight is recommended for maintaining idle horses. (Appendix Table V.)

449. Nutrients required in various types of work.—It is evident that the horse at work must receive a larger supply of nutrients than when idle, and that the amount needed will depend on the severity of the work done. Let us then consider what types of work the horse performs. His work usually consists of a more or less complex combination of the following simple kinds: (1) Locomotion, or traveling along a level course without a load; (2) raising the body, with or without a load, against the force of gravity in ascending a grade; (3) carrying a load; (4) draft, or hauling a load. A horse drawing a load up a hill combines all of these types. He is (1) advancing and at the same time (2) raising his body. Likewise he is (3) carrying the harness and (4) hauling the load. In descending the hill the horse will be called upon to perform even a fifth type of labor, bracing himself to prevent too rapid a descent.

Much experimental work was done many years ago by Wolff, Grandeau and LeClerc, and more recently by Zuntz and his associates to determine the amounts of nutrients required in the various types of work. Wolff's experiments were with a sweep-power constructed so that the amount of work performed could be measured. Zuntz, in conjunction with Lehmann and Hagemann, conducted hundreds of tests with horses working on a tread-power so built that the distance traveled and the work performed were accurately measured. The animals breathed thru a tube inserted in the windpipe, by which means the oxygen inhaled and the carbon dioxid exhaled were accurately determined. To such gaseous intake and

outgo was added that which passed thru the skin and vent as determined by placing the animal in a Pettenkofer respiration apparatus. (73-4)

450. Locomotion and carrying a load.—Considerable energy is expended by the horse in merely moving his body along a horizontal road, since he must lift his body at each step and propel it forward. Yet in this work of locomotion, no useful work is accomplished in the mechanical sense. Zuntz found that when walking at a speed of 2.5 miles per hour, the 1,100 pound horse, carrying a 44-lb. harness, required 0.240 therm of net energy in addition to the maintenance requirement when idle, for each mile he traveled on a level road. When the horse carried a load of 220 lbs. on his back, the amount of net energy expended was increased 24 per ct. above the amount required for the same distance and at the same speed without a load.

451. Work of draft.—When the horse pulls a load and thus accomplishes useful mechanical work, obviously he will expend more energy than when merely moving his own body along a level road. Zuntz found that in performing each 1,000 foot-tons of work of draft (which is about an hour's work for a horse weighing 1,400 lbs.) the horse expends 2.078 therms of net energy.

452. Influence of speed on work.—The horse is at his best for drawing loads when moving at a rate of 2 to 2.5 miles per hour. If held to a slower pace and especially if urged to move faster, his efficiency decreases, and he must expend more energy in doing a given amount of work. Thus 26 per ct. more net energy was required in the trials of Zuntz when a horse traveled a mile on a level road at a speed of 3.5 miles per hour than when the same distance was covered at a speed of 2.5 miles an hour. When his gait is increased to a trot, nearly twice as much energy is required per mile of travel as at the slower walk. His efficiency continues to become less as the speed increases, until when worked at a speed of 11.25 miles an hour, he can accomplish less than one-tenth of the amount of work he can perform at a moderate pace.

Among the reasons why more energy is required to do a certain amount of work at a fast pace are: (1) In trotting or galloping the rise and fall of the body are much greater than in walking. Energy is wasted in these movements, and hence a smaller amount is available for onward movement. (2) At a rapid pace the work of the heart is increased, the temperature rises, and much heat is lost thru the evaporation of water from the skin and lungs in the effort to keep the body temperature normal. The proportion of the food which produces heat is thus increased, while less can be converted into work.

Grandeau[12] states that a horse walking 12.5 miles per day was kept in condition on a daily allowance of 19.4 lbs. of hay, while a ration of 24 lbs. was insufficient when the same distance was covered at a trot. A horse hauling a load 12.5 miles daily at a walk was sufficiently nourished by a ration of 24.6 lbs. of hay, while one of 36.2 lbs.—all the

[12] London Live Stock Journal. 1894, p. 49.

horse would eat—was not enough to maintain its weight when the same amount of work was done at a trot.

To keep mail-coach horses, which were pushed at top speed, in condition, they could often be worked but one hour a day, traveling only eight miles even on good roads. While a pound of additional load makes but little difference to a draft horse, with running horses the requirement of speed makes it necessary that the weight carried (rider and saddle) be as small as possible. An ounce of additional loading may make a difference of a yard or more in half a mile of running.

453. Influence of grade.—In going up a grade, the horse must not only propel his body and the load over the ground but must also raise them against the force of gravity. In ascending a grade of 10.7 ft. in 100 ft. Zuntz found that the horse expends three times as much energy per mile as when traveling on a level road. The steeper the grade, the greater the energy required. For instance, in ascending a grade of 18.1 ft. in 100, nearly 5 times as much energy was expended as when moving on a level road.

On the other hand, in going down a gentle incline, owing to the force of gravity less energy is required than on a level road, which results in a saving of nutrients. If the grade is steeper than 10 feet in 100, however, the horse must expend energy in bracing himself and the load against a too rapid descent and hence uses as much as when traveling on the level. On a still steeper downward slope more energy is expended than on a level course. Obviously, a great saving of feed may be effected by a proper use of wagon brakes in a hilly country.

454. Requirements for work horses.—It has been previously pointed out in Chapter VI that normally the carbohydrates and fats furnish the energy used in producing work, and no more protein is usually broken down during work than during rest. Hence, the nutrient requirements of horses at work resemble those of fattening animals. With both these classes, after growth is completed the ration may consist largely of carbohydrates and fat, with only sufficient protein to ensure complete digestion of the ration.

It is not necessary, and is often not advisable nor economical, to furnish as much digestible crude protein in the ration as stated in the Wolff-Lehmann standard. (See Appendix Table IV.) Indeed, horses at hard work have been fed for considerable periods without harm on rations having nutritive ratios as wide as 1 :28.0[13] However, as shown in Chapter III (**84**), when the nutritive ratio is wider than 1 : 8.0 or 1 : 10.0, the digestibility of the ration is decreased and feed is wasted. It would therefore not seem advisable to feed horses a ration having a wider nutritive ratio than this, except possibly under unusual conditions when protein-rich roughages or concentrates were not at hand, or were unusually high in price.

[13] Grandeau and Alekan, Ann. Sci. Agron., 1901, II, p. 38.

McCampbell[14] of the Kansas Station studied this question in his experiments at Fort Riley, the most extensive yet carried on with horses in the United States. From trials in which prairie hay and corn were fed with and without a nitrogenous supplement, he concludes that a ration having a wider nutritive ratio than 1:8 is inadvisable. It is not necessary to employ protein-rich concentrates to secure this nutritive ratio when legume hay forms the larger part of the roughage allowance.

455. Computing rations for work horses.—The amount of energy expended by horses in each of the types of work they do has been determined with considerable exactness in the investigations of Zuntz and others which have been referred to in the previous paragraphs. However, the results are of theoretical rather than practical interest, for the work of most horses varies greatly from day to day and is usually of a complex nature, difficult to divide into these simple types. All that can commonly be done is to estimate whether the horse is performing light, medium, or heavy work, and then compute a ration which meets the standard for this degree of labor. A horse actually working about 7 hours a day or more at reasonably hard labor, should be considered at hard work, while one which works but 3 to 4 hours a day should be classed as at medium work, unless the work is unusually severe or is performed at a rapid rate. Horses working less than this are at light work. Such a rough classification will suffice as a guide in computing approximate balanced rations for work horses. The amount of concentrates fed to the individual horses should be adjusted so as to maintain them in the desired condition, as further discussed in Article **530**.

The older feeding standards prescribe more total digestible nutrients or net energy than actually seem to be required for draft horses doing ordinary farm or city work. From a study of rations fed horses in feeding trials at the Wisconsin[15] and other[16] experiment stations, and of rations used in large stables, the recommendations given in the Morrison (Modified Wolff-Lehmann) feeding standards have been formulated. These are given in Appendix Table V.

It is believed that these standards will be found to meet American conditions satisfactorily. It will be noted that the allowance of total digestible nutrients for the horse at hard work is nearly double that for the idle horse, while the amount of dry matter is increased to a much less extent. This means that the ration must consist more largely of concentrates as the work becomes harder. A narrower nutritive ratio is recommended as the severity of the work increases, for the horse at severe labor seems to be benefited by a fairly liberal supply of protein. As is pointed out in a later chapter, it is imperative that the concentrate allowance of hard-worked horses be reduced on days when they are idle, or azoturia may result. (**530**)

[14]Kan. Bul. 186.

[15]Wis. Bul. 302, pp. 63-4; unpublished data.

[16]Kan. Bul. 186; Ill. Bul. 150; Ohio Bul. 195; N. H. Bul. 82; etc.

Most farm horses actually work but 1,000 hours a year, or less, the average time worked per day being but 3 to 4 hours thruout the year. However, during the rush seasons farm horses usually work long hours and should then be classed as at hard work. (513)

456. Severe work.—The more severe the labor which the horse performs, the larger must be the supply of net nutrients. Since the ration must not have undue bulk, this necessitates a large proportion of concentrates, high in net energy content. On the other hand, the more severe the labor, the smaller must be the allowance of roughage, for coarse feeds are of low value for producing work, and when given in undue amount hinder breathing, thru the distension of the digestive tract, thus placing an increased burden on the already hard-worked animal. However, some roughage must be supplied even during severe labor. (107) It must be remembered that rich feed, carelessly administered, brings danger; hence especial care must be used in feeding the horse at severe work.

457. Variations in body weight.—During exercise and work a loss in body weight occurs, due to the greater oxidation, or breaking down, of the nutrients in the body and to the largely increased evaporation of water. Grandeau and LeClerc[17] found that 2 horses lost on the average 2.3 lbs. each when walked for 148 minutes without drawing a load, while on hauling a load at a trot for 79 minutes each lost 9.3 lbs. A horse performing a certain amount of work at a trot gave off 20.6 lbs. of water vapor, nearly twice as much as when doing the same amount of work at a walk, and over 3 times as much as when at rest. Such losses diminish the amount of energy available for the production of work.

When horses which have been idle for a period and consequently have soft muscles are put at hard work, they will often lose 50 to 100 lbs. in weight, especially unless they are gradually accustomed to the work. Due to the large capacity of their digestive tracts, the weights of horses or cattle on consecutive days, taken at a uniform hour and under similar conditions of feed and care, may vary 15 to 30 lbs. or even more. This shows the necessity of carrying on feeding experiments for considerable periods of time and with several animals in order to escape, or rather lessen, the errors which are introduced into the calculations thru accidental variations in the weights of the animals studied.

458. Efficiency of the horse as a motor.—Such a large part of the mechanical power used on farms is furnished by horses that it is of much interest to determine the efficiency with which they actually convert into useful work the nutrients in the feed they consume. The investigations of Zuntz show that the horse turns into useful work from 31 to 36 per ct. of the net energy he expends, in addition to that needed to maintain his body when idle. This does not take into consideration the energy of the food which is lost in the excreta, or in mastication, digestion, and assimilation. (76-9) To gain a true idea of the efficiency of the horse as a motor, we must compute his over-all efficiency, or the

[17] Ann. Sci. Agron., 188, II, p. 276.

percentage of the total energy in the feed which he is able to convert into useful work.

A 1,500-lb. horse should readily haul a load having a draft of 150 lbs. at a speed of 2.5 miles per hour for 8 hours a day. In doing this the horse will perform 7,920 foot-tons of useful work, not including the work of moving his own body along the roadway. Expressed in therms, this amount of work is equal to 5.13 therms.

For such a horse a ration of 15 lbs. timothy hay, 8 lbs. corn, 8 lbs. oats, and 1.5 lbs. linseed meal will be satisfactory. This ration will furnish about 57.19 therms of gross energy. Dividing 5.13 therms (the useful work accomplished) by 57.19 therms (the gross energy of the feed) gives an over-all efficiency for this horse of 8.95 per ct. This is higher than the average over-all efficiency of 65 modern farm tractors, which was found to be 8.05 per ct. in tests at the University of Nebraska in 1920. (143)

However, farm horses do not work every day, tho they must eat every day. Therefore the over-all efficiency for the entire year is much lower than for a 24-hour period in which the horse does a good day's work. On the average, the yearly over-all efficiency of farm horses, which usually work only about 800 to 1,000 hours a year, is about 2 to 3 per ct.[18] Obviously, any factor which increases the number of hours of work a horse does during the year increases his over-all efficiency and reduces the actual cost of his labor per hour, for less of his feed will then go for maintaining him when idle.

459. Reducing the cost of horse labor.—Horse labor makes up a relatively large part of farm operating expenses. Moreover, it is, above all other items of expense, the one which can be profitably reduced by good methods of farm organization. Hence a clear understanding of the following ways in which this expense can be lessened is of prime importance:[19]

(1) *By economical feeding, care, and management.* Farm management surveys have shown that it costs some farmers nearly twice as much to feed their horses as it does their neighbors, tho the horses may do but little more work. Thru economical feeding the cost of horse labor may thus be greatly reduced.

(2) *By raising good colts.* Even tho the direct profits to be made in raising colts may not be large, successful farmers, at least in the corn belt and westward, find it economy to raise enough well-bred colts to replace the older horses worn out or sold to avoid depreciation.

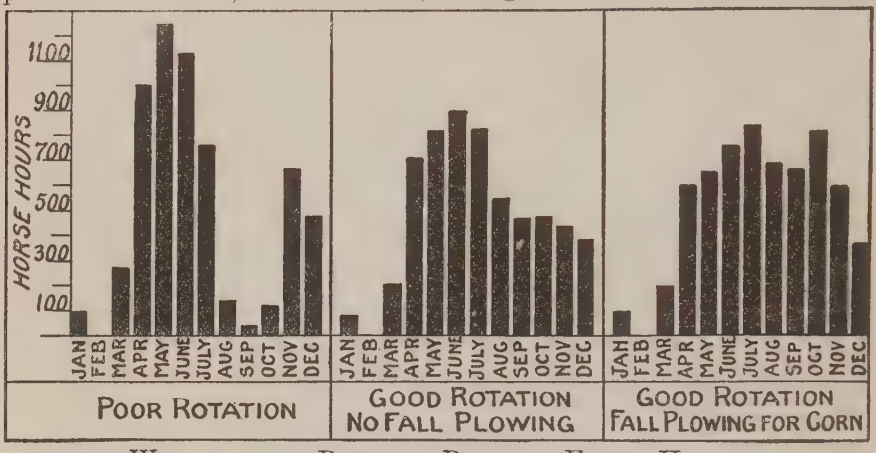
(3) *By reducing depreciation charges.* As is pointed out in the following chapter, many farmers largely avoid the depreciation in the value of horses due to their becoming old, by raising good colts, starting them to work when 3 years old, and selling them after working 4 or 5 years, when they are yet in their prime and bring good prices.

[18]E. A. White, Breeder's Gazette, June 2, 1921, p. 997.

[19]Largely adapted from Handschin, Andrews, and Rauchenstein, Ill. Bul. 231.

(4) *By having the farm of adequate size.* When a farm is too small neither horse nor man labor can be utilized most efficiently.

(5) *By securing an even distribution of horse labor.* The crop rotation should be so planned that the horse labor will be distributed as evenly as possible thruout the year. The accompanying illustration clearly shows that when the crop rotation is poorly planned, the peak load of horse labor will be much higher than under a wise rotation, necessitating the keeping of extra horses, merely for this peak load. An important advantage of live stock farming is that productive work is provided for horses, as well as men, during the winter.



WELL-PLANNED ROTATION REQUIRES FEWER HORSES

The columns indicate the hours of horse labor required each month on a 200-acre corn-belt farm with a poor rotation of 120 acres corn, 50 acres oats, 10 acres mixed hay, and 20 acres pasture; compared with a good rotation of 80 acres corn, 40 acres oats, 40 acres winter wheat, 20 acres clover hay, and 20 acres clover pasture. The poor rotation required over 1,150 hours of horse labor in one month, while the peak load was reduced to 900 hours with the good rotation, even when no fall plowing was done. When the land for corn was plowed in the fall, the peak load was still further reduced, and the labor better distributed over the year, making possible a saving in number of horses needed. (From Illinois Station).

(6) *By efficient use of horses.* The good farm manager will see that his fields are so laid out, and buildings, yards, paddocks, and lanes so arranged that just as much labor as possible is saved, both of men and horses. Furthermore, he will save much man labor by having gang plows, and harrows, drills, cultivators, etc. of large size so that teams of 3 horses or more can be used. By means of the improved multiple hitches, a team of 5 or even more horses can be worked readily by one man. Such a farmer will also be foresighted in his work and not allow work which can be done just as well at some other time, to interfere with the peak loads of planting, cultivating, and harvesting the crops, all of which cannot be delayed without serious loss. For instance, by doing considerable plowing in the fall, the peak load in the spring can

be reduced and often one or more horses dispensed with. Last, but not least, he will keep no more than the minimum number of work horses necessary to meet efficiently the peak load of horse labor during the year.

460. The horse vs. the tractor.—Many farmers are perplexed to know whether it will be economy for them to purchase a tractor to replace some of the work horses on their farms. Tho each farm is somewhat of an individual problem, recent investigations in various farming districts show the general principles which should be considered in deciding this problem.

Among the advantages claimed for the tractor is its ability to do heavy work, such as plowing, during the peak load of horse labor in a shorter time than it can be done with horses, thus permitting the planting of crops at just the right time. This advantage can, however, be largely gained with horses by using teams of 3 or more animals with suitable plows and other implements. Often claims are made that the tractor increases crop yields thru deeper plowing and more thoro preparation of the seed bed. In surveys of the results from tractors in the corn-belt, most of the farmers report no noticeable effect on crop yield thru using tractors. In some cases increases in yield were reported, and in a less number decreases in yield were mentioned, due to the packing of the soil when damp by the tractor.

Perhaps the chief advantage in the use of the farm tractor comes in the actual displacement of horses. It also relieves the horses which cannot be displaced of some of the heaviest work during the rush seasons, so that they may need a little less feed. The actual displacement of horses is less than often supposed, for a tractor is suited to perform but relatively few of the many kinds of work which the adaptable horse can perform. On the average, farm tractors in the corn-belt, where the level topography and freedom from stones make conditions especially favorable for them, are used only about 30 to 45 days a year, including both draft and belt work.

In a survey of the results from tractors on Illinois farms, averaging 294 acres, Handschin, Andrews, and Rauchenstein[20] found that on the average 2.38 horses were disposed of after a tractor had been purchased. Reynoldson[21] reports from a survey of farm tractors on corn-belt farms, averaging 324 acres, that 2.5 horses were disposed of per farm where tractors had been used for a year or more. In Minnesota, 127 farmers reported an average displacement of 2 horses per farm after a tractor was used.[22]

In the Illinois survey it was found that the saving of man labor is not a large item in favor of the tractor, for the peak load of man labor in the corn-belt comes in June and July, during corn cultivation, haying, and harvesting, while the peak load of horse and tractor labor

[20]Ill. Bul. 231. [21]U. S. D. A. Farmers' Bul. 1093.

[22]Patterson, Mowry, and Cavert, Minn. Agr. Exten. Div., Spec. Bul. 31.

comes in April and May, during plowing, disking, harrowing, and seeding.

Including the expenses for fuel, lubricants, repairs, depreciation, and interest on the investment, the annual cost of operating a farm tractor of average size will be $300 to $600, according to Handschin, Andrews and Rauchenstein. They conclude that on the average corn-belt farm growing less than 240 acres of crops, the horse costs can not be reduced enough by the use of a tractor to offset the cost of operating it. They point out that this does not mean that every corn-belt farm with over 240 cultivated acres should use a tractor, nor that smaller farms will always find a tractor unprofitable, for the conditions on the particular farm must be taken into consideration. For instance, there may be a special need for belt power on the farm or in the neighborhood, which would justify the purchase of a tractor where otherwise it would not be profitable. When the cost of feed and the price of horses are relatively low compared with the cost of tractors and their operation, farmers will rely entirely on horses on farms where they would otherwise use a tractor.

II. Preparation of Feed; Water; Salt

461. Chaffing hay.—With horses at ordinary farm work, which have abundant time to chew their feed thoroly, cutting or chaffing hay probably does not result in sufficient saving to warrant the expense, unless hay is high in price. However, in stables where large numbers of horses are kept, the hay is frequently chaffed. Somewhat less is then wasted, especially if it is of rather poor quality, and dust may be easily laid by sprinkling with water. The grain allowance is often mixed with part of the chaffed hay, which forces the horses to eat the grain more slowly and chew it more thoroly. A common practice in Europe is to mix cut straw with chaffed hay, more straw thus being eaten than would otherwise be the case.

462. Soaking or cooking grain.—When such grains as wheat and barley cannot conveniently be rolled or ground, they should be soaked before feeding, to soften the kernels. Ear corn that is so dry and flinty as to injure the horses' mouths should also be soaked or ground.

While once common, the custom of cooking even a small portion of the feed given to horses has almost ceased. Johnstone,[23] who had the practice thoroly ingrained into his nature by early Scotch experience, out of his later observations writes: "Time was when I considered the feeding of sloppy stuff a necessity in properly wintering brood mares, but experience has shown me that dry food is best. Therefore I prefer uncooked food. . . Time was when I believed that for stallions during the season it was an excellent plan to give a mash of boiled barley every Wednesday and Saturday night. . . . The experiments have, however, shown that the addition of this material to a horse's grain ration makes no appreciable difference in the manner in which the grain is digested." (425-9)

[23] The Horse, p. 77.

463. Grinding grain.—Whether or not it pays to grind or crush oats for horses is a question often discussed. In trials during 2 summers Morrison, Fuller, and Bohstedt found at the Wisconsin Station[24] that crushing oats for horses at hard work resulted in a saving of slightly over 5 per ct. In these trials about 94 lbs. of crushed oats were equal to 100 lbs. of whole oats, where the teeth of the horses were kept in good condition. From this one can readily determine whether it will pay to crush or grind oats with oats at the local price.

Where whole oats are mixed with cut or chaffed straw or hay, the percentage of kernels which are not masticated and which pass thru the digestive tract is still smaller than where the oats are fed separately. Lavalard[25] concluded from his extensive trials with cab, omnibus, and army horses in France that grinding oats did not pay when the oats were mixed with such cut roughage. As shown later (**475**), thruout the corn belt corn is usually fed on the cob or as shelled corn, tho some authorities recommend the use of corn-and-cob meal or coarsely ground corn meal. It is reasonable to hold that when horses are hard worked and have but little time in the stable, or when their teeth are poor, it is well to grind their grain. All small, hard grains, such as wheat, barley, rye, and kafir, should always be ground or, better, rolled.

464. Watering horses.—On theoretical grounds various authorities have advised watering the horse before giving him grain, to prevent possible flushing of the grain out of the stomach into the small intestine. Extensive tests[26] have shown, however, that horses may be watered before, after, or during a meal without interfering with the digestion or absorption of the food eaten. Therefore, individual circumstances and convenience should determine the time of watering, but when a system is once adopted it should be rigidly adhered to, for a change from one system to another lessens the appetite. A horse long deprived of water or having undergone severe exertion should be watered before being fed, but it is dangerous to allow a horse much water when very warm. A moderate drink taken slowly will refresh him and do no harm.

About 10 to 12 gallons, or 100 lbs., of water should be provided daily for each horse. In warm weather and when at hard work, horses will drink more water than at other times, owing to the greater evaporation of water from the body. The nature of the feed also affects the quantity of water drunk. When fed protein-rich feeds, and especially alfalfa hay, horses drink more water than when fed carbonaceous feeds.

465. Salt.—The horse shows great fondness for salt and thrives best when regularly supplied with it. A reasonable allowance is two ounces per head daily. Horses at hard work require somewhat more salt than those laboring less severely, for a considerable amount of salt is excreted in the perspiration.

[24]Wis. Bul. 302, pp. 63-4.

[25]Expt. Sta. Rec. 12, p. 12.

[26]Tangl, Landw. Vers. Stat. 57, 1902, p. 329.

III. Hints on Feeding and Caring for Horses

466. General hints on caring for horses.—There is great truth in the Arab saying, "Rest and fat are the greatest enemies of the horse." Regular exercise or work is necessary for health and a long period of usefulness. A mature horse should travel not less than 5 to 6 miles daily and the highly-fed colt should have abundant exercise. Whenever a horse is not working, reduce the grain, even to one-half, to avoid digestive troubles, as is pointed out in Chapter XX. (530)

467. The stable.—To keep them in good health, horses should be housed in well-ventilated quarters and be protected from drafts. Cool quarters with good ventilation are far preferable to warm, close stables. Captain Hayes[27] states that in some large city stables of Russia the temperature was often kept 80° F. above that of the outside air in winter. Under these conditions trouble from influenza, inflammation of the eyes, and diseases of the respiratory organs were common. On the other hand, in the cavalry remount stables, roomy, clean, and well-ventilated, the horses kept in excellent health. He further states that previous to 1836, the mortality of horses in the French army was enormous, the annual loss varying from 180 to 197 per 1,000 animals. Enlargement of the stables and better ventilation reduced this mortality to less than one-seventh the former figures. In all cases horses should be protected from drafts, and judgment must be used in blanketing them in extreme weather.

468. Blanketing and clipping.—Horses at work prove more efficient and last longer when reasonably protected against sudden changes in temperature and cold rains. It is important to blanket the horse in cold weather whenever his work ceases and he is forced to stand in the cold for even a short time. Stable blankets keep the coat in better condition, but when they are used it is especially necessary to protect the horse when standing idle out of doors.

The heavy coat which the horse grows for winter protection has certain disadvantages with the work animal under his artificial conditions. The horse with a long coat sweats unduly at work and his system is thereby enervated and relaxed, rendering him especially subject to colds. As it is difficult to completely dry such a horse after a day's work, it may often be advisable to clip him early enough in the fall to permit the growth of a lighter coat for protection before severe weather begins. However, he should not be fall clipped unless he is carefully protected from cold at all times when not working. Horses are often clipped in the spring after the shedding process has begun, but before the new coat has started, thus, it is claimed, preventing as great a draft on the animal's system and certainly obviating the annoyance of the shedding coat, especially disagreeable in the case of gray horses.

[27] Stable Management and Exercise, 1900, p. 198.

469. Grooming.—As the horse at severe labor gives off several pounds of perspiration daily, when this evaporates considerable solid waste material is left on the animal's coat. Thoro and careful grooming is necessary to remove such body waste and keep the pores open and the skin healthy. Aside from the better appearance which results, proper grooming pays in the greater efficiency of the hard-worked animal. It is best to groom the work horse at night after a severe day's work, so that he may rest more comfortably. As idle horses running at pasture sweat little, consume green grass and other laxative foods, and have abundant opportunity to roll, grooming is unnecessary. While grooming should be thoro, a dull currycomb is preferable to a sharp one, and a brush should be used on the tender head and legs.

470. Care of teeth.—The teeth of the horse often wear irregularly, especially those of old horses, leaving sharp points and ragged edges that cause pain, prevent proper mastication of food, and in extreme cases actually cause starvation. Many horses that are poor in flesh and wear staring coats, despite a reasonable supply of food, owe their condition to poor teeth alone. The teeth should therefore be frequently examined and cared for, the irregularities being removed by a float or guarded rasp. The first, or milk teeth, are also apt to remain too long in the young horse's mouth, causing crooked permanent teeth. In such cases the milk teeth should be removed with forceps.

471. General hints.—To be most efficient in converting the energy of his feed into useful work, the horse must labor in a properly fitting harness. The collar needs special attention, for the capacity of many a horse is decreased because he wears an ill-fitting collar. It is vitally important that his feet be properly shod, so that the weight and wear are evenly distributed on the joints of the ankle. The other mechanical principles which determine the efficiency of work, such as the correct use of eveners, the proper adjustment of traces and of line of draft, the distribution of the load on the wagon, and the influence of size of wheel, width of tires, and character of road bed must all be given due consideration. In starting the day the horse should be gradually warmed to his work, so that his collar will be shaped to his shoulders, his muscles in proper trim, his bowels relieved, and breathing and heart action quickened before he is put to extreme exertion. It is likewise well to cool him off gradually at the end of a trip or of the day's work before returning to the stable. That he may rest in comfort, his stall should be well bedded.

No other farm animal is so strongly the creature of habit as is the horse, and in no way is he more so than in the matters relating to food and its administration. Sudden changes in quantity and variety should be avoided. A quick change from oats to corn may bring on colic, but changing from corn to oats is less dangerous. An abrupt change from old to new hay or oats, or from late to early cut hay, is hazardous. Wilted grass or new mown hay is more dangerous than fresh grass. Horses are especially susceptible to poisoning thru eating moldy grain or forage.

(397) Any unusual feeding stuff, such as silage, roots, apples, etc., should be given in small quantities at first, and changes in kind and quantity of any food should be made gradually. As a rule some hay should be fed at the same time the concentrates are given, in order to distend the stomach and intestines properly. As is shown in the following chapter (492), more horses are injured by gorging on hay than by being given too little.

472. Supervision of feeding.—In stables where many horses are maintained, a group or row of animals should remain in the care of the same attendant, the whole establishment being under the watchful supervision of the superintendent. While we can estimate quite closely the amount of food to be given a hundred or a thousand horses, there should always be modifications and concessions to individual members of the establishment to be recognized and provided for by the guiding mind,—one horse should have a little more than the regulation allowance, and the next possibly a little less, the object being to keep each in the desired condition. Usually it is not well to leave the feeding of horses to their own driver, for he has likes and dislikes, and the favorites are quite certain to receive more than their proper allowance of grain, while the others suffer. A watchful superintendent must ever be on the alert to see that each animal secures the needed provender.

FARM HORSES USED IN FEEDING TRIALS AT WISCONSIN

Experiments during two years with these horses proved that crushing oats makes a saving of only about 5 per ct. Some of the buildings of the College of Agriculture are shown in the background.

BARLEY IS A SATISFACTORY FEED FOR WORK HORSES

Other trials at the Wisconsin Station showed that crushed barley is worth more than crushed oats per pound for horses.

CORN IS THE CHIEF GRAIN FOR MANY CORN-BELT HORSES

Because of its lower cost and its higher feeding value per pound, corn is widely fed to horses in the corn belt.

OATS ARE UNEXCELLED FOR CARRIAGE OR SADDLE HORSES

While oats excel any other single grain or concentrate for such horses, a proper combination of other concentrates will give just as satisfactory results.

FILLIES EATING GRAIN ON PASTURE

It is important to keep foals growing properly by supplying enough concentrates. These may be chiefly the farm grains.

CHAPTER XIX

FEEDS FOR HORSES

I. Carbonaceous Concentrates

In most localities the usual ration for horses is restricted to but one or two kinds of grain with no more variety in the roughages. Due to custom and prejudice, many insist that these particular feeds are by far the most economical and satisfactory that can be fed. Yet, in traveling from one district or country to another we find a large number of feeds successfully used for horses.

In the northern Mississippi valley the ration is quite generally oats and timothy hay, while in the South corn is the chief concentrate, with dried corn leaves, legume hay, and other roughages. On the Pacific coast crushed barley is the common grain used, with hay from the cereals. In Europe various oil cakes and beans are often fed. In Arabia, Persia and Egypt barley is the only grain, while in sections of India, a kind of pea, called gram, is the usual food. In some districts very unusual feeds are used for horses. Bamboo leaves are fed as a complete substitute for ordinary grass and hay in the hill districts of eastern Burmah. In France, Spain, and Italy, besides the grasses, the leaves of limes and grape vines, the tops of acacia, and seeds of the carob-tree have all been employed. "In some sterile countries," according to Loudon,[1] "horses are forced to subsist on dried fish, and even vegetable mould. In parts of India, salt, pepper, and other spices are made into balls, as big as billiard balls, with flour and butter, and thrust down the animal's throat."

As further shown in this chapter, a long list of feeds are well-suited to horses. Hence, to feed these animals economically, due attention must be given to the prices of the various feeds which are locally available, and a combination selected which will maintain them in good condition at a minimum expense.

473. Oats.—This grain, so keenly relished by horses, is the standard with which all other concentrates are compared. (223) Oats are the safest of all feeds for the horse, due to the hull, which, tho furnishing little nutriment, gives the grain such bulk that not enough can be eaten at one time to cause digestive trouble from gorging. In the stomach, oats form a loose mass, which is easily digested, while such heavy feeds as corn tend to pack, causing colic.

As shown previously (463), unless oats are high in price and crushing or grinding can be done cheaply, such preparation will not pay for horses

[1] Encyclopedia of Agr., 1886; Article, Feeding of Horses.

with good teeth. They should be thus prepared, however, for horses with poor teeth, and for foals. New and musty oats should be avoided as they may cause colic. Some horses are inclined to eat their oats too rapidly, or "bolt" them without thoro chewing. To prevent this, a little chopped hay may be mixed with the oats or some whole corn cobs can be placed in the feed box with the oats.[2]

Even oats do not always form a perfect concentrate, for Axe[3] states that the strongest advocates of this feed in England recognize that for hunters and for other horses in severe weather the ration is improved by the addition of beans.

474. Substitutes for oats.—Because of their universal favor and the wide demand for them, oats are often not an economical grain where expense must be considered. Fortunately, both practical and scientific trials alike teach that other single grains or mixtures of concentrates may be substituted for oats without injury to the condition, wind, endurance, or even the spirit of the horse.

The Arab steed, so renowned for mettle and endurance, is fed no oats, but chiefly barley. After experiments covering 35 years, involving the feeding of 16,000 omnibus horses in Paris and some 17,000 French army horses, Lavalard,[4] the great French authority on the nutrition of the horse, concluded that the substitution of other feeds for oats, while effecting a great saving, had not in the slightest lowered the productive power of the horses.

The entire success attained with grain mixtures containing no oats, but properly balanced in nutrients and having the requisite bulk, shows that in making up the ration for the horse, just as with other animals, the prices of the various available feeds should always be considered. The many grains and by-products which may be successfully fed to the horse in place of oats are discussed in the following articles. From these studies and a knowledge of ruling market prices for feeds, each feeder may determine for himself the most economical rations to employ.

475. Indian corn.—Next to oats, Indian corn (maize) is the common grain for horses in America, being most largely used in the middle and southern portions of the corn belt and southward in the cotton states. Millions of horses and mules on American farms and plantations get their strength from corn, scarcely knowing the taste of oats. While corn does not have all of the superlative qualities of oats, nevertheless, because of lower cost and higher feeding value, it will always be extensively used in this country wherever large numbers of horses must be economically maintained. (201)

When corn forms a large part of the concentrate allowance, the ration should be balanced by concentrates or roughages rich in protein and mineral matter, in which this grain is deficient. As corn is a heavy, highly concentrated feed, care must also be exercised in limiting the

[2] Bell and Williams, U. S. D. A., Farmers' Bul. 1030.

[3] The Horse, etc., 1907, vol. 8, p. 347. [4] Expt. Sta. Rec., 12, 1900, p. 13.

amount fed to the needs of the animal. In all cases changes from oats to corn or other feeds should be made gradually. To neglect of these principles may be ascribed the unfavorable results that sometimes follow the feeding of this grain.

Thruout the corn belt the grain is usually fed on the cob or shelled. Ear corn is safer to feed than shelled for it keeps better, and the horse eats it more slowly, chewing it more thoroly. If corn is ground for horses with poor teeth or those working long hours, it should be ground coarsely, for fine meal forms a mass in the stomach which is difficult to digest and may cause colic. Feeding corn in the form of corn-and-cob meal is preferable to using ground corn, for the cobs supply bulk, making the feed more like oats in physical nature. In experiments at the North Carolina Station[5] with 3 teams of mules and 1 team of horses, Burkett found corn-and-cob meal as valuable as an equal weight of shelled corn. (423)

476. Corn with carbonaceous hay.—Since a ration composed of corn and carbonaceous roughage, as timothy or prairie hay, is deficient in protein, even for work animals, it will be improved by the addition of some nitrogenous concentrate. This is shown by the following results secured by McCampbell at the Kansas Station[6] in a 140-day trial with 1,150-lb. artillery horses, performing more severe labor than the average farm horse:

Corn with carbonaceous hay requires supplement

Average ration	Gain or loss in weight	Nutritive ratio	Daily cost of feed per 1,000 lbs. live weight
	Lbs.		Cents
Lot I			
Oats, 12 lbs. Prairie hay, 14 lbs.	16.3	1: 7.9	20.3
Lot II			
Shelled corn, 12 lbs. Prairie hay, 14 lbs.	−29.3	1:11.5	17.5
Lot III			
Shelled corn, 6 lbs. Wheat bran, 3 lbs. Linseed meal, 1 lb. Prairie hay, 14 lbs.	3.9	1: 8.4	16.7

In winter, when the weather was cold and the work moderate, there was no apparent difference between the horses in Lots I and II. However, as the weather grew warmer and the work more severe, the horses in Lot II, fed the unbalanced ration of corn and prairie hay, lost weight, tho their endurance, wind and spirit were not injured. The well-balanced ration fed Lot III was fully as satisfactory as the oat ration and cheaper than even the straight corn ration.

Hooper and Anderson of the Kentucky Station[7] report that the skin of mules fed corn with timothy and oat hay was not so soft nor their hair so sleek as in the case of mules fed the well-balanced mixture of 3 parts corn, 1 part wheat bran, and 1 part linseed meal.

[5] N. C. Bul. 189. [6] Kan. Bul. 186. [7] Ky. Bul. 176.

Beginning in 1874, the Paris Omnibus Company, then employing nearly 10,000 horses averaging about 1,200 lbs. each, conducted extensive feeding trials with Indian corn. Feeding corn exclusively with hay from the grasses was found to depress the spirits of the horses, and accordingly a mixture of 6.6 lbs. of corn and 12.1 lbs. of oats was adopted, varying somewhat with different horses. Thru this combination the company effected a saving of from $200,000 to $300,000 yearly. The Paris Cab Company, also beginning at about the same time to feed corn in place of oats, had such satisfactory results that it almost entirely ceased feeding oats.

From these trials, and others with some 17,000 French army horses, Lavalard[8] concluded: "Experiments have demonstrated that corn can replace oats in the ration of both army and cavalry horses, and if substituted weight for weight, it increases the nutritive value of the ration. .....The horses fed the corn ration were used the same number of hours in military drill, and in the maneuvers were ridden at the same gait as those fed oats, and it was practically impossible to perceive the least difference in the two classes. The army officers, prejudiced as they naturally were, were forced to admit that all the horses showed the same energy and vigor. Careful records kept show that sickness and mortality were the same for the horses on the two rations."

477. Corn and legume hay.—With legume hay for roughage to supply the lacking protein and mineral matter, corn may be successfully fed as the only concentrate to mature horses at general farm work. In a 48-week trial by Carmichael at the Ohio Station[9] one horse in each of 3 farm teams was fed ear corn with mixed clover and timothy hay for roughage, while the other one was fed oats with the same roughage. In spite of the fact that the corn-fed horses received only the same weight of ear corn, including cobs, as the others did of oats, they maintained their weights nearly as well. With corn at 40 cents and oats at 30 cents a bushel, using corn in place of oats saved over one-fourth in the cost of feed.

Trowbridge fed one mule in each of 2 farm teams at the Missouri Station[10] shelled corn and the other one oats, all receiving mixed clover and timothy hay, for 364 days, when the rations were reversed and the feeding continued for another 364-day period. The mules fed corn maintained their weight slightly better than those fed oats and at 21 per ct. less expense for feed, with oats at $0.40 and shelled corn at $0.50 per bushel. Both Carmichael and Trowbridge report that the corn-fed animals endured hard work during hot weather as well as those fed oats, and that the corn was not detrimental to health or spirit.

478. Barley.—This grain is extensively employed for horse feeding in Africa, in various parts of the Orient, and in Europe. In this country it is extensively used on the Pacific coast, especially in California. Owing to the fact that the grains are hard and small, barley should be crushed or ground for horses. (463) Crushing is preferable, as barley

[8] Expt Sta. Record, 12, 1900, p. 14. [9] Ohio Bul. 195. [10] Mo. Bul. 114.

meal forms a pasty, unpleasant mass when mixed with the saliva in the mouth. Morrison, Fuller, and Bohstedt[11] found in trials at the Wisconsin Station, in which one horse in each of 10 teams at hard work was fed crushed barley and the other crushed oats for 2 months and the rations then reversed, that crushed barley was worth about 10 per ct. more than crushed oats, pound for pound. In trials by Shepperd of the North Dakota Station[12] and Lavalard[13] of France the whole grain was not quite so valuable as a given weight of whole oats. Since barley is not as bulky as oats, there may be slightly more trouble from colic when it is fed. (226)

479. Wheat.—Altho the price of sound wheat usually prohibits its use as a horse feed, that which has been frosted or otherwise damaged, if not moldy, may be fed with economy. Wheat should preferably be rolled and fed in moderate amounts only, mixed with a bulky concentrate, such as bran, or with chaffed forage, to avoid digestive troubles and skin eruptions. (215)

480. Rye.—Rye is not especially palatable to horses, and is apt to produce digestive troubles if fed as the only grain, or if the change to rye is made abruptly. It is satisfactory when fed as only part of the concentrate mixture along with better liked feed, and preferably with oats or some other bulky concentrate. (232) As rye kernels are small and hard they should be ground or preferably rolled. Most of the trouble experienced in feeding rye has doubtless been due to over feeding or using grain which was spoiled or contaminated with ergot. (396)

481. Grain sorghums.—In the regions where they flourish, the various grain sorghums are extensively employed for horse feeding, tho somewhat less valuable than corn. Being small and hard, they should be ground or crushed, and if possible mixed with bran or middlings, for they tend to produce constipation. These grains may also be fed unthreshed in the heads along with the forage. (235-42)

482. Cane molasses.—Thruout the sugar-cane districts cane molasses is often the most economical source of carbohydrates for work animals. Dalrymple[14] of the Louisiana Station, collecting data from 47 Louisiana sugar plantations employing over 5,000 work animals, chiefly mules, found that an average of 9.5 lbs. of cane molasses was fed daily to each animal, the maximum being 21 lbs. The molasses was usually mixed with corn (ground with both cob and husks), other concentrates, or cut hay, but was sometimes fed separately in troughs or poured on uncut roughage. The ration was usually balanced with legume hay or cottonseed meal. Planters held that the use of molasses reduced digestive disturbances and improved the health and endurance of the animals, with a saving of 10 to 50 per ct. in cost of feed. No scouring, such as would be produced by large quantities of beet molasses, was noted. Berns[15] re-

[11] Wis. Bul. 319, pp. 68-9.
[12] N. D. Bul. 45.
[13] Expt. Sta. Rec., 12, 1900, p. 14.
[14] La. Bul. 86, 1906; Breeder's Gaz., 48, 1905, p. 277.
[15] Amer. Vet. Rev., 26, 1902, pp. 615-623.

ports improvement in the condition of 100 heavy truck horses in New York on feeding 1 quart of molasses daily, diluted with water and mixed with grain and cut hay. Dalrymple and Berns both obtained satisfactory results on feeding molasses to driving horses.

In the northern states, a quart or so a day of molasses may be profitable as an appetizer or as a tonic for horses out of condition, even when molasses is too high in price to be a cheap source of carbohydrates. (280)

483. Beet molasses and molasses mixtures.—Because of its laxative properties, beet molasses must be fed only in limited amounts, but when not given in excess, it has given satisfactory results and is well liked by horses. (277) It may be thinned with warm water and mixed with cut fodder or fed in such mixtures as molasses-beet-pulp, alfalmo, etc. (281) In trials with 130 hard-worked horses of a Budapest transportation company, Weiser and Zaitschek[16] obtained entirely satisfactory results for months with a ration, per 1,000 lbs. live weight, of 4.1 lbs. beet molasses mixed with 5.6 lbs. wheat bran and fed with 5.7 lbs. corn and an unlimited allowance of hay. One pound of molasses replaced 0.78 lb. of corn. When the molasses was increased to 5.5 lbs. per 1,000 lbs. live weight no injurious effect on the health of the animals was observed, but the molasses-bran mixture proved too sticky to be palatable.

Various molasses feeds, especially those containing some alfalfa meal, are extensively used in feeding horses in cities and in some sections of the eastern and southern states. Good quality feeds of this character are palatable to horses, have sufficient bulk to prevent trouble from colic, and are usually slightly laxative.

Molasses and many of the molasses feeds on the market are carbonaceous feeds, deficient in protein, and at the high prices often asked are uneconomical sources of carbohydrates. (281)

484. Miscellaneous concentrates.—*Rough rice* is an economical feed for horses and mules in the southern states, when low in price compared with other cereals. In trials with 2 mules at the Louisiana Station Dalrymple[17] gradually substituted rough rice for an equal weight of cracked corn, feeding as high as 8 lbs. per day with good results. As this grain is small and extremely hard, it should always be ground or crushed. It is even lower than corn in protein and hence should be fed with protein-rich feeds. (234)

Dried beet pulp is often refused by horses when fed alone, but when mixed with other concentrates may be used as a portion of the ration, when not too high in price compared with its feeding value. Allowances of 5 to 6.6 lbs. per head daily have given good results in Europe. (276)

Sugar, fed in small amounts, has been recommended for horses. On feeding one lot of 18 artillery horses oats and prairie hay and another lot the same ration, except that 0.5 lb. of sugar was substituted for 2 lbs. of oats, McCampbell[18] of the Kansas Station found that the sugar-fed

[16] Landw. Jahrb., 37, 1908, pp. 138-149. [17] La. Bul. 122. [18] Kan. Bul. 186.

horses sweat more easily than the others, altho showing excellent coats of hair and good appetites. He concludes that while a small amount of sugar may be fed as a conditioner, it is not an economical substitute for the various grains ordinarily available. (282)

II. Protein-rich Concentrates

485. Wheat bran.—Bran is one of the most useful feeds for horses, because of its bulky nature and mild laxative properties. (218) If not more freely provided, its use once a week is desirable. A good plan is to feed work horses on Sundays and other idle days a mixture of one-third bran and two-thirds oats or other grain, when grain alone is fed on work days. In cases of constipation, a wet bran mash may be used, which has a more pronounced laxative effect than dry bran fed in mixture with other feed. As the immediate effect of a bran mash is somewhat weakening, it should be given at night and preferably before a day of rest.

When low in price, bran may be profitably fed in larger amounts as a partial substitute for oats. Fed with timothy hay, a mixture of equal weights of bran and corn has been found equal to one of half oats and half corn[19]. As bran is low in lime, if heavy allowances of it are used, feeds should be given which are high in lime, or lime should be added in the form of ground limestone, etc. (98)

486. Wheat middlings; shorts.—Tho furnishing more nutriment than bran, middlings or shorts are not as desirable for the horse, because of their heavier character. When fed to horses, they should be mixed with bulky feed and should not form over one-fourth the concentrates, as they tend to produce colic, the danger being great with some horses. (220)

487. Linseed meal.—Linseed meal, rich in protein and having tonic and somewhat laxative properties, is an excellent supplement for rations poor in protein. (254) Not over 1 to 1.5 lbs. per head daily is ordinarily fed, due both to its high price and its laxative effect. Linseed meal is useful as a laxative for constipated animals and for bringing into condition run-down horses with rough coats. It gives bloom and finish in fitting horses for show or sale, and is excellent to feed in spring to hasten the shedding of the hair.

In a trial with 1,170-lb. artillery horses McCampbell of the Kansas Station[20] secured excellent results with a ration of 1 lb. linseed meal, 4 lbs. oats, 6 lbs. corn, and 12 lbs. prairie hay. As less was needed to balance the ration, linseed meal was considerably more economical as a supplement than wheat bran. In a trial at the Iowa Station[21] with 3 teams of farm horses Kennedy, Robbins, and Kildee found a mixture of 1 part oil meal and 10 parts shelled corn, fed with timothy hay, too laxative for horses at hard work in summer. A mixture of 1 part oil meal, 4 parts oats and 12 parts corn, proved as satisfactory as one of 6

[19]Burkett, N. H. Bul. 82. [20]Kan. Bul. 186. [21]Iowa Bul. 109.

parts oats and 4 parts corn. Substituting oil meal for a large part of the oats saved 1.6 cents in daily cost of feed.

488. Cottonseed meal.—This protein-rich feed is not popular among horsemen, as it may cause digestive disturbances and even poisoning unless fed with care and in strictly limited amounts. When properly fed, however, it may be used with entire success as a protein-rich supplement to balance the ration. (250) Bell and Williams of the United States Department of Agriculture[22] advise that generally not over 1 lb. be fed daily per 1,000 lbs. live weight, tho some horses may be fed more with satisfactory results. Only bright, high-grade meal should be fed to horses. Cottonseed meal is a heavy feed and is not usually relished by horses when fed alone. It should therefore be mixed with better-liked bulky concentrates, such as whole or crushed oats, or corn-and-cob-meal. At first not over one-fourth pound per head daily should be fed and the allowance should be gradually increased as the horses become accustomed to the taste and odor of the meal. At the North Carolina Station[23] Curtis found it impracticable to feed mules on cottonseed meal and ear corn. Altho fairly satisfactory, a mixture of 1 part cottonseed meal with 6 parts shelled corn was less relished than 1 part of meal with 3 of corn-and-cob meal, the remaining corn being fed on the cob. Louisiana planters attribute their success in feeding cottonseed meal largely to the fact that they mix it with blackstrap molasses.

Disproving the claim that work stock fed on cottonseed meal suffer from short wind and weak eyes, Curtis reports that trials covering 3 years showed no such harmful effects when the meal was properly fed. Judge Henry C. Hammond of Augusta, Georgia,[24] reports that for 5 years he fed 10 pleasure and work horses each 1 lb. of cottonseed meal daily without a single sick animal or one not ready for work, due, he holds, to the fact that the meal was always mixed with some light concentrate. In a 154-day test at the Iowa Station[25] with 3 work teams fed timothy hay, 6 per ct. of cottonseed meal proved as effective as 8 per ct. of linseed meal in balancing a grain mixture of 15 per ct. oats and the remainder corn.

489. Dried brewers' grains.—Formerly this by-product was often an economical substitute for oats. At the New Jersey Station[26] in a trial with 4 teams of 1,000-lb. street car horses, fed a ration of 8 lbs. oats, 2 lbs. bran, 4 lbs. shelled corn, and 6 lbs. hay, Voorhees substituted an equal weight of dried brewers' grains for the oats in the ration of one horse in each team. The change produced no ill effects on the horses, which traveled not less than 24 miles per day. The conclusion was reached that pound for pound good quality dried brewers' grains were

[22] U. S. D. A., Dept. Bul. 929; Farmers' Bul. 1030.

[23] N. C. Buls. 215, 216.

[24] Pamphlet "Cottonseed Meal for Horses and Mules;" information to the authors.

[25] Iowa Bul. 109.

[26] N. J. Rpt. 1892.

fully equal to oats. Not being particularly palatable, dried brewers' grains should be mixed with other concentrates. Hooper and Anderson[27] of the Kentucky Station report the grains somewhat constipating for horses and mules. (228)

490. Leguminous seeds.—Field peas, soybeans, cowpeas, velvet beans, and horse beans may all be used in limited amounts as protein-rich supplements for horses. (256, 261-4) All these leguminous seeds should be ground and should not form over one-third the concentrate mixture, else they may cause digestive trouble, owing to their heavy character. In Europe horse beans and other varieties of beans are widely used in feeding.

491. Miscellaneous protein-rich concentrates.—Gluten feed is most commonly used for dairy cattle, but may be fed to horses in limited amounts, mixed with better-liked feeds, as a protein-rich supplement to balance the ration. (210)

Gluten meal was used successfully as a supplement to corn meal in a trial at the Iowa Station[28] but proved rather unpalatable to horses. (211)

Dried distillers' grains, fed by Lindsey[29] at the Massachusetts Station as one-fourth of the concentrate allowance to horses, gave excellent results. Fed by Plumb[30] at the Indiana Station as one-third of the grain allowance, they proved fairly satisfactory with some horses, but unpalatable to others. (283)

Cocoanut meal is a safe, tho rather unpalatable, feed for horses.[31] It may replace oats to the extent of one-fourth the concentrates when economy justifies the measure. (260)

Peanut meal may be fed very satisfactorily to horses as a protein-rich supplement. As high-grade peanut meal is as rich in protein as is cottonseed meal, only 1 to 2 lbs. per head daily will be needed to balance a ration low in protein. (258)

Oil cakes and meals from sunflower seed, rape seed, sesame, etc. are fed to horses in different parts of Europe in quantities of 2.2 to 4.4 lbs. per horse daily with good results. (259)

Tankage and blood meal were found by Burkett at the North Carolina Station[32] to be useful for run-down, thin horses, 1 to 2 lbs. of tankage or 1 lb. of blood meal being employed. Pott[33] states that blood meal has given excellent results in horse feeding. (270-1) As such animal by-products are unpalatable to horses, they must be mixed with well-liked feeds.

Velvet bean feed was found satisfactory for horses by Lindsey at the Massachusetts Station[34] when forming about 18 per ct. of the concentrate mixture. (264)

[27] Ky. Bul. 176.
[28] Iowa Bul. 109.
[29] Mass. Bul. 99.
[30] Ind. Bul. 97.
[31] U. S. D. A., Farmers' Bul. 1030.
[32] N. C. Bul. 189.
[33] Handb. Ernähr. u. Futter., III, 1909, p. 515.
[34] Mass. Bul. 188.

III. Carbonaceous Roughages

492. Excess of roughage injurious.—We have seen previously that horses can not live on concentrates alone, even on oats with their straw-like hulls. (**107**) An excess of roughage, on the other hand, is also injurious. When we recall that the stomach of the horse has a capacity of only 19 quarts (**35**), while the 4 stomachs of a cow may hold 267 quarts, it is evident that the horse at hard work cannot well derive most of its nourishment from roughage. Thru carelessness or mistaken kindness, the mangers are often kept filled with hay, especially in the case of farm horses. The horse then gorges himself on this provender, with a staring coat, labored breathing, and quick tiring as the least serious, tho probably the most noticeable results. For this animal there should always be a definite, limited daily allowance of hay, given mostly at night when there is ample time for its mastication and digestion. Many digestive disturbances are caused by forcing the horse to work with his stomach distended by coarse feed. More horses are injured by feeding too much than too little hay. On feeding 1 horse in each of 2 teams doing ordinary farm work all the timothy hay they would eat, in addition to oats, while the others were given about two-thirds as much hay, Clark[35] at the Montana Station found that those fed the smaller amount had more life and sweat less. In another trial a horse receiving 7.5 lbs. of grain daily was allowed all the early-cut timothy hay it wished, and ate so much that it failed to gain in weight, had a staring coat, and lacked life.

493. Timothy hay.—Altho not rich in digestible nutrients, timothy hay is the standard roughage for the horse thruout the northeastern United States. The freedom from dust of good timothy hay commends it as a horse feed, and it is an excellent roughage for animals whose sustenance comes mostly from concentrates. While timothy cut too green makes "washy" hay, it should not be allowed to stand until it becomes woody and indigestible. A reasonable allowance of timothy hay is 1 lb. daily per 100 lbs. of animal. So far as possible the other roughages here considered will be compared with timothy hay as the standard. (**312**)

494. Cereal hay.—On the Pacific coast, especially in California, the cereal hays—barley, wild oat, wheat, etc.—are extensively employed as roughages for horses. The excellence of the speed horse and the endurance of the work horse of the coast region attest the merits of these feeds. In some cases where racing horses have been sent to the East, cereal hay was forwarded with them for their nourishment. Thruout the Rocky Mountain region oat hay is of considerable importance. Cereal hay may often be advantageously employed for horse feeding in the eastern United States. At the North Carolina Station[36] Burkett found that hay from oats cut in the milk stage compared favorably with clover and cowpea hay for horses. (**318**) When cereal hay contains much grain, the allowance of concentrates fed should be reduced accordingly.

[35] Mont. Bul. 95, 1913. [36] N. C. Bul. 189.

495. Prairie hay.—Thruout the western states prairie hay from the wild grasses forms an excellent roughage for the horse. From trials lasting 110 to 140 days with 453 artillery horses, McCampbell[37] of the Kansas Station concludes that timothy hay is slightly more valuable than prairie hay, but that when timothy hay costs 10 per ct. more than good prairie hay, the latter is more economical. (325)

496. Brome hay.—This hay, commonly grown in the northern plains region, proved fully equal to timothy in a trial by Shepperd at the North Dakota Station[38] in which 1 horse in each of 2 work teams was fed brome hay and oats, while their team mates received timothy and oats. (316)

497. Sudan grass hay; southern hays.—*Sudan grass hay* is palatable to horses and makes a satisfactory roughage for them, much superior to millet hay. (322)

Bermuda hay and *Johnson grass hay* were found about equal to timothy hay in feeding value in a trial by Lloyd at the Mississippi Station.[39] (320, 321)

498. Millet hay.—Hay from the various millets may be fed satisfactorily to horses, if cut before it is too mature and if fed as only half the roughage. (317) When fed as the only roughage to horses for long periods, millet hay has produced serious lameness and swelling of the joints and increased action of the kidneys.[40] This was perhaps due to a considerable amount of millet seed in the hay, as it is claimed that these have a harmful action on the kidneys.[41]

499. Sorghum hay.—Forage from the sweet sorghums, when properly cured, is superior to corn forage for horses. It usually deteriorates rapidly in value after midwinter unless well cured and kept in a dry place. Moldy, decaying sorghum forage is especially dangerous to horses. Kafir, tho not quite so palatable as the sweet sorghums, is extensively and profitably used for horse feeding over a large region in the southwestern states. (308)

500. Corn fodder and corn stover.—Thickly grown fodder corn or even bright corn stover, when properly cured and cared for, are among the best of roughages for the horse, for they are palatable and usually quite free from dust if not allowed to become moldy. (302-4) For stallions, brood mares, idle horses, and growing colts good corn forage is usually an economical substitute for timothy hay. In a trial by Burkett at the New Hampshire Station[42] corn stover was successfully used as the only roughage for farm horses doing light work in winter. Horses fed 12 lbs. of corn stover a head daily, with 7 lbs. corn and 7 lbs. of oats or bran, maintained their weights practically as well as others fed 12 lbs. of timothy hay in place of the corn stover. With timothy hay usually selling at 2 to 4 times as much as corn stover, the great saving

[37] Kan. Bul. 186.
[38] N. D. Bul. 45.
[39] Information to the authors.
[40] Hinebauch, N. D. Bul. 26.
[41] U. S. D. A., Farmers' Bul. 1030.
[42] N. H. Bul. 82.

thru using the latter is apparent. Corn stover and corn fodder should usually be shredded or cut, to reduce the wastage. (305)

501. Straw.—Owing to its large content of fiber and consequent low value for the production of work, but little straw can be fed to hard-worked horses, for their digestive tracts are not so constructed as to utilize such feed well. (35) On the other hand, horses doing little or no work and having ample time for chewing and digesting their feed may be wintered largely on bright straw or corn stover, instead of costly hay. Farm horses should not be wintered in the barnyard on straw and corn stover only, without grain, for they will then be in no condition for the severe work of spring. It must be borne in mind that straw is very low in protein, and some protein-rich feed should always be used to balance the ration when straw is fed. In Europe nearly all rations for horses contain straw, those hardest worked receiving the least. In feeding value the straws rank in the following order: Oat, barley, wheat, rye, the last-named having but slight value. (328-9)

502. Corn stover and straw reduce feed bills.—The saving which may be made thru the use of such cheap roughages as corn stover and straw in place of a large part of the timothy hay, and of substitutes for oats is well illustrated in a trial by Norton at the Michigan Station[43] in which 2 lots, each of 6 farm horses doing moderate work, were fed the following rations for 10 weeks in winter: Lot I was fed exclusively on high-priced timothy hay and oats (with a light feed of bran once a week). These horses received 11 lbs. of oats and 20 lbs. of timothy hay a head daily. The roughage fed Lot II consisted of 8.6 lbs. shredded corn stover and 4.3 lbs. oat straw, with only 4.2 lbs. timothy hay. Only 3.1 lbs. oats was fed these horses, the rest of the concentrates being 4.2 lbs. ear corn and 2.6 lbs. of a mixture of equal parts of bran, dried beet pulp, and linseed oil cake, with 4.2 lbs. of carrots for succulence and as an appetizer.

During the trial the horses in Lot I, fed the ration of timothy hay and oats, costing 29.6 cents a day, each lost an average of 11 lbs. in weight. On the other hand those getting the cheaper but well-balanced ration gained 14 lbs. each at a feed cost of 17.7 cents per day—a saving of 40 per ct. in the feed bill.

503. Carbonaceous roughages require supplement.—It should be remembered that hay from the grasses, corn fodder, corn stover, sorghum and kafir forages, and straw are all low in protein. Therefore, when these roughages are used exclusively, protein-rich concentrates should be fed to balance the ration. This fact, which has already been brought out (476), is also shown in other trials by McCampbell[44] in which horses fed only corn and prairie hay did not thrive as well as others fed corn and oats, or corn, bran, and linseed meal with the prairie hay.

[43] Mich. Bul. 254.

[44] Kan. Bul. 186.

IV. Legume Hay

504. Legume hay.—When given in moderation, well-cured legume hay can without question be fed to horses with entire satisfaction. The widespread prejudice against legume hay for horse feeding is largely due to these rich roughages having been fed in excess or to the poor quality of the hay used. Since alfalfa and clover hay are more like concentrates in nature than is timothy hay, less is needed to replace a given amount of timothy. However, horses are especially fond of good legume hay, and often gorge on it unless the allowance is restricted. (**492**)

It is important that legume hay for horses be bright and well-cured, for that which is dusty and otherwise injured in quality may cause heaves. Dampening dusty hay before feeding helps somewhat, but it is far better to prevent the mold and dust by proper curing.

505. Clover hay.—Because clover hay is often carelessly made and loaded with dust, it is disliked by many horsemen, particularly for feeding roadsters. This objection does not apply to clean, properly-cured clover hay. For driving horses, clover hay may be mixed with timothy hay or bright straw, while for horses at ordinary farm work it may form the only roughage. The value of this hay for farm horses is shown by a trial at the Illinois Station[45] by Obrecht with 6 teams of 1,375-lb. horses, in which one horse in each team received clover hay and the other timothy. After 196 days the rations were reversed and the trial continued for 20 weeks. The average results on the two rations are shown in the following table:

Clover vs. timothy hay for horses

Average ration	Av. gain in weight Lbs.	Daily work Hours
Clover-fed horses		
Corn, 6.9 lbs. Oats, 7.3 lbs.		
Oil meal, 0.46 lb. Bran, 0.61 lb.		
Clover hay, 15.6 lbs.	15.5	7.3
Timothy-fed horses		
Corn, 6.8 lbs. Oats, 7.2 lbs.		
Oil meal, 0.53 lb. Bran, 0.60 lb.		
Timothy hay, 15.6 lbs.	3.0	7.3

Altho most of the teamsters were prejudiced in favor of timothy hay at the beginning, they later reported that they could observe no difference in the spirit of the horses or their ability to endure hot weather. The horses fed clover hay had glossier coats and their bowels were looser, but not objectionably so for doing hard work. (**347**)

Wilcox and Smith[46] state that second-crop clover hay may cause slobbering. The reason is unknown, but some horsemen state that adding bran or apples to the ration tends to prevent the trouble.

506. Alfalfa hay.—Because it is cheap and abundant, this legume hay furnishes the sole roughage for horses upon tens of thousands of farms

[45]Ill. Bul. 150. [46]Farmer's Cyclopedia of Live Stock, 1908, p. 323.

and ranches in the West. (339) With the increasing culture of alfalfa in other sections of the country more and more alfalfa hay is likewise being fed to horses in these districts. It is therefore important to learn the conditions essential to its successful use. When the horse is allowed to gorge on alfalfa hay, in addition to having his stomach over-distended with the bulky feed he receives an excess of highly nitrogenous material. This must be excreted thru the kidneys, overworking them, and even, according to McCampbell[47] leading to a chronic inflammatory condition if excessive feeding is long continued. The alfalfa allowance for horses should therefore be limited, McCampbell advising that those at work receive not more than 1.2 lbs. per 100 lbs. live weight. The hay should be free from dust, mold, and smut, and should not be cut until almost mature, for hay from early cut alfalfa, as commonly advised for cattle, is too laxative, or "washy," for horses.

In view of the prejudice among liverymen and owners of driving horses against alfalfa, a 140-day trial was conducted by McCampbell with 1,160-lb. artillery horses, doing more hard work than the average farm team thruout the year, a considerable portion at a trot and no small amount at a gallop. The horses in Lot I were fed alfalfa hay with 2 lbs. oats and 8 lbs. corn, while those in Lot II received timothy hay, with half as much corn and 4 times as much oats.

Alfalfa vs. timothy hay for horses

Average ration		Av. gain or loss per head Lbs.	Daily cost of feed per 1,000 lbs. live weight Cents
Alfalfa-fed horses			
Shelled corn, 8 lbs. Oats, 2 lbs.	Alfalfa hay, 10 lbs.	25.6	12.95
Timothy-fed horses			
Corn, 4 lbs. Oats, 8 lbs.	Timothy hay, 14 lbs.	—7.7	19.21

The alfalfa-fed horses, getting 2 lbs. less grain and 4 lbs. less hay than those fed timothy, showed no shortness of wind, softness, or lack of endurance and gained in weight while the others lost. The cost of the alfalfa-hay ration was only about two-thirds that of the timothy-hay ration.

Obrecht found at the Illinois Station[48] that farm horses fed alfalfa hay when doing hard work maintained their weight on 20 to 22 per ct. less grain than others fed timothy hay. Similar favorable results with alfalfa hay are reported by Carroll[49] (Utah Station), Faville[50] (Wyoming Station), and Gramlich[51] (Nebraska Station). In an Illinois trial by Edmonds and Kammlade[51a] very satisfactory results were secured when farm horses and mules were fed only ear corn and alfalfa hay.

[47]Kan. Bul. 186.
[48]Ill. Bul. 150.
[49]Utah Cir. 43.
[50]Wyo. Bul. 98.
[51]Nebr. Exten. Bul. 28.
[51a]Ill. Bul. 238.

In the West alfalfa hay, often with straw in unlimited amount, is a common maintenance ration for idle horses. Merrill at the Utah Station[52] found 20 lbs. of alfalfa hay per day sufficient to maintain a 1,400-lb. horse when not working, while Emery[53] at the Wyoming Station found that 13.8 lbs. of alfalfa hay and 2.25 lbs. of oat straw would maintain a 1,000-lb. idle horse.

507. Alfalfa meal.—When good quality alfalfa hay is available, it is not economical to pay a higher price for alfalfa meal, for horses waste but little of such hay, if properly fed. Moreover, alfalfa meal is dusty. This irritates the air passages of the horse and may cause serious trouble. In addition, the meal is disagreeable to handle.[54] While the dust may be laid by wetting, this takes considerable time. (**344**)

508. Miscellaneous legume hays.—Hay from soybeans, cowpeas, field peas, sweet clover, lespedeza, and other legumes may be used with good results in horse feeding if it is well-cured and fed in moderation. In a feeding trial at the North Carolina Station Burkett[55] found that cowpea hay combined with corn-and-cob meal made a satisfactory work ration, and that cowpea hay with a reasonable quantity of corn could be substituted for bran and oats. (**357**)

Lespedeza hay was found decidedly superior to timothy, Johnson grass, or Bermuda hay in a trial with growing mules by Lloyd at the Louisiana Station.[56] Even with lespedeza hay at $15 a ton and Bermuda or Johnson grass hay at $11 a ton, the cost of feed per pound of gain made by the mules was one-fourth less when the roughage was lespedeza hay. (**360**)

V. Pasture and Other Succulent Feed

For horses receiving but little exercise succulent feeds are especially beneficial on account of their "cooling" and laxative effect. A limited amount of succulent feed is often employed thruout the year in Europe for work horses and even for drivers.

509. Pasture.—Horses at pasture not only obtain succulent feed, but must exercise to secure it. Good pasture will maintain idle horses satisfactorily; for those at hard work pasture without grain is insufficient. Not only do the various tame and wild grasses furnish pasture for horses, but as these animals are not subject to bloat, they may graze the legumes as well. City horses are often turned on pasture so that their feet may recover from the ill effects of hard pavements.

To help in keeping farm teams thrifty it is a good plan to allow them regularly the freedom of a pasture at night and on idle days. Concerning this practice Bell and Williams of the United States Department of Agriculture write:[57] "There will be an increased tendency toward

[52]Utah Bul. 77.
[53]Wyo. Rpt. 12.
[54]McCampbell, Kan. Bul. 186.
[55]N. C. Bul. 189.
[56]Information to the authors.
[57]U. S. D. A., Farmers' Bul. 1030.

sweating while at work but this is not of great importance when the benefits are considered. For work horses that are given pasture, other laxative feeds should be taken out of the ration. Timothy hay may be used as the roughage, and the concentrate ration should include grains that are not laxative in character, thus making a properly balanced ration. A necessary precaution is to avoid a sudden change to green feed; where a pasture crop is included in the ration for work horses, the practice should be continuous, not intermittent."

510. Corn silage.—Until recent years little corn silage has been fed to horses and mules, but it is now being used with success on many farms. (**296**) It should not be the only roughage but should serve as a partial substitute for hay. Because of its bulky nature, horses at hard work can not consume much silage, but it is well suited to idle horses, brood mares, and growing colts, due to its slightly laxative effect and its tonic and appetizing qualities. Since poisoning may result from feeding moldy silage to horses, only that of good quality should be used, and this should be fed under very careful supervision. (**397**)

Horses should be accustomed to silage gradually, and some may not take to it readily at first. Not over 10 to 15 lbs. per head daily had best be fed to horses, tho larger allowances have been satisfactory in some instances. If the silage contains much corn, the amount of grain fed should be reduced accordingly. In trials by Trowbridge at the Missouri Station[58] corn silage has been used with success and economy as part of the roughage for wintering idle brood mares.

511. Roots; tubers; fruits.—The only importance of roots for horse feeding in most sections of this country is as an aid to digestion, for the cereals generally furnish nutriment at lower cost. (**365**) Carrots, especially relished by horses, are great favorites with horsemen when cost of keep is not considered. They are most helpful when it is necessary to carry horses along in high condition, as in stallion importing establishments. (**372**) Parsnips rank next in value. (**373**) In his extensive studies of roots for the horse Boussingault found[59] that it required 400 lbs. of rutabagas (swedes) or somewhat over 350 lbs. of carrots to replace 100 lbs. of good meadow hay. (**370**)

Boussingault found artichokes were eaten greedily and with good results by horses, about 275 lbs. of the tubers replacing 100 lbs. of hay. (**375**) Potatoes, according to Pott,[60] may be fed raw or cooked in amounts as high as 17.5 lbs. per day along with suitable dry feed. Larger quantities may cause digestive disturbances. Boussingault states that 280 lbs. of cooked potatoes mixed with cut straw replaced 100 lbs. of hay. (**374**)

As horses are usually fond of fresh fruit, it may sometimes be profitably fed in moderate allowance when there is no market for it. Dried fruits, slightly injured and therefore unsalable, have been successfully fed to horses. (**385**)

[58]Mo. Cir. 72; Bul. 179, p. 18.

[59]Rural Economy, p. 400.

[60]Handb. Ernähr. u. Futter., II, 1907, p. 368.

512. Wet beet pulp.—Wet beet pulp is unsuited for work horses, according to Pott,[61] altho it may be fed to idle horses at the rate of 22 to 44 lbs. per head daily. Larger quantities are said to be injurious. Clark[62] of the Utah Station reports that colts were allowed constant access to pulp at a sugar beet factory for several years without trouble arising.

VI. Cost of Keep

513. Cost of keeping farm horses.—The cost of horse labor is a matter of great interest and importance to all farmers, especially at the present time when tractors are competing with horses as sources of draft power. Cooper of the United States Department of Agriculture[63] secured data on the cost of keeping horses from 1909 to 1914 on 27 farms in Illinois, Ohio, and New York. The detailed cost of keeping these horses under pre-war conditions is shown in the following table:

Average yearly cost of keeping farm horses under pre-war conditions

Gross costs	*Illinois*	*Ohio*	*New York*
Feed and bedding	$68.75	$76.86	$91.25
Labor	13.99	27.48	22.09
Interest	7.90	8.66	9.43
Stabling	4.95	7.18	12.98
Use of equipment	3.82	5.00	5.85
Shoeing	.86	2.35	4.56
Misc. (including depreciation)	5.62	1.04	12.22
Total	$105.89	$128.57	$158.38
Credit for manure	5.24	8.20	13.36
Net cost	$100.65	$120.37	$145.02

The horses on the Illinois farms worked on the average 1,053 hours a year and were fed on the average 4,500 lbs. of concentrates (practically all corn and oats) and 1,540 lbs. of hay. In addition 2,684 lbs. of other roughage (straw and fodder) was fed or used for bedding. The horses on the average were pastured 148 days. The Ohio horses worked only 866 hours and were given 3,347 lbs. concentrates (chiefly oats and corn), 4,180 lbs. hay, and 1,480 lbs. other roughage (for feed and bedding). They were pastured on the average 68 days. The New York horses worked 1,020 hours, but were fed considerably less concentrates, due to the higher price of concentrates in the northeastern states. They received much more hay, 6,560 lbs., and 2,953 lbs. other roughage (for feed and bedding) and were pastured only 34 days.

The cost of feed and bedding was about two-thirds of the net cost of keeping these horses. The other largest item of expense was for man and horse labor in feeding and caring for the horses. Many of the minor items are often overlooked by farmers in estimating the cost of horse labor. The depreciation varied widely on these farms, being

[61]Handb. Erähr. u. Futter., III 1909, p. 299.
[62]Utah Bul. 101.
[63]U. S. D. A. Bul. 560.

lowest where young horses were used for a few years and sold before they had depreciated much in value. Due to this practice, on these particular Ohio farms the horses on the average increased in value during the year instead of depreciating. Where a horse is kept on the same farm during its useful life, 8 to 10 per ct. depreciation should be figured per annum, on the basis that it will begin work as a 3-year-old and continue at work to the age of 13 to 15 years.

The average cost of horse labor per hour was 9.56 cents for the Illinois, 13.90 cents for the Ohio, and 14.22 cents for the New York farms. The gross cost of keeping farm horses under present conditions may be slightly higher than shown in these surveys. However, any such increase will be fully offset by the fact that the credit given for the manure produced per horse is entirely too low for present-day conditions, even taking into consideration the fact that some of the excrement is voided by horses on the roads, and thus lost. This will be noted on comparing the credits for manure in the previous table with the data in Chapter XVII. (441)

Johnson and Green of the Missouri Station[64] secured data over a period of 4 years, 1912 to 1915, from 36 different Missouri farms, including records on 320 horses and mules. The total yearly cost of keep per head was $91.22, not including any charge for depreciation in value of the work animals. Of this, $65.65, or 72 per ct. of the total, was for feed; $11.03 for labor; and $14.54, for miscellaneous expenses.

On the average these horses and mules worked 1,152 hours a year, of which 655 hours was at field work and 497 hours at miscellaneous labor. They consumed on the average 2,262 lbs. corn, 698 lbs. oats, 3,586 lbs. hay, and in addition pasture worth $3.33, other roughage valued at $4.17, and other concentrates costing $1.11 per head. The average total cost per hour of horse labor on these farms was 7.9 cents. The feed cost was considerably lower on the farms where the horses were fed corn as the chief grain than where oats were largely fed.

The feed cost per hour of actual work performed was 5.0 cents on the farms where mules were the chief work animals, 5.6 cents where geldings were mainly used, and 6.0 cents where most of the work animals were mares. Tho the cost of labor per hour is thus apparently higher with mares, this does not mean that on many farms it is not profitable to keep high-grade mares as work animals and raise foals from them.

With the return of prices for feed substantially to pre-war levels, the horse will continue to prove on most farms an efficient competitor of the tractor in the economy with which he performs work. Just as many farmers do not take into consideration all the factors which make up the cost of horse labor, perhaps the majority do not fully appreciate all the costs of tractor operation, including the heavy expenses for interest on the investment, the rapid depreciation, and the large bills for repairs. (458-60)

[64] Mo. Bul. 152.

CHAPTER XX

FEEDING AND CARING FOR HORSES

Skill and good judgment enter into the success or failure in feeding and caring for horses even more than is the case with other classes of stock. Two grooms may have similar conditions as to horses to be cared for, work performed, and feed bins to draw from, yet they may secure widely different results. In one case the team has an action and style which at once announce it in the best of condition. In the other the lagging step, dull eye, and rough coat tell better than words the lack of judgment in feeding and management. The unsatisfactory condition has not necessarily been brought about by any saving at the feed bin and hay mow. Indeed, the good horseman will usually feed his team the more economically. Nevertheless the principles of successful horse feeding are simple and easily understood. If the few necessary rules and precautions are observed, coupled with good judgment at all times, there should be no difficulty in maintaining horses in fit condition to work most efficiently.

No one can study the practices of successful horsemen without being strongly impressed with the fact that there are several ways of reaching the desired end of high finish and fine action with the horse. If the reader finds the counsel here given on feed and management not entirely to his satisfaction, let him remember that we have chosen a rational and generally applicable course, conceding that good results may also be obtained by following other systems.

I. The Brood Mare, Foal, and Growing Horse

514. Feed and care of brood mare.—It has been estimated that only 60 per ct. of the mares that are bred each year produce living colts.[1] Yet the greater part of this enormous loss can be prevented by proper feed, care, and management of the brood mare. Idleness, the bane of horse breeding, should be avoided. (466) Working mares are more certain of bringing good foals than idle ones, but judgment must always be used in working them. Pulling too hard, backing heavy loads, wading thru deep mud, or other over-exertion must be avoided. When not working, the mare should be turned out daily for exercise. As foaling time approaches, the work should be lightened, and preferably discontinued 3 days to a week before foaling, altho in many instances mares have been worked up to the day of foaling without harm.[2] When laid off, she should

[1] McCampbell, Kan. Bul. 186.

[2] Harper, Management and Breeding of Horses, p. 284.

not stand in the stall without exercise. A roomy, well-lighted, well-ventilated box stall with wide doorway and ample bedding are none too good at such times. Mares heavy in foal are apt to be cross and quarrelsome, but they should always be handled gently.

The feeding of the working brood mare is easier than that of the idle one. The chief essential is a well-balanced ration of good feeds, containing plenty of protein, lime, and phosphorus. An abundance of these is especially needed by immature pregnant mares and pregnant mares which are suckling foals, since in addition to the demand from the developing fetus there is the draft for the growing body of the mother in the one case, and for milk secretion in the other. (113, 121, 147) All feeds should be free from dust, mold, or decay, which might cause abortion. Mares used only for breeding purposes do well without grain when on nutritious pasture. With insufficient pasture and in winter some grain should be given. The feed should not be too concentrated, but should have considerable bulk or volume. The bowels must be kept active thru the proper use of such feeds as bran, linseed meal, roots, etc.

515. Gestation period and foaling time.—The average period of gestation for the mare is about 11 months, or 340 days, tho it may vary quite widely. William Russell Allen of Allen Farm,[3] Pittsfield, Massachusetts, from records of 1,071 foals produced by trotting mares during 15 years, found the maximum gestation period 373, the minimum 319, and the average 340 days. A wider range was observed by Tessier,[4] who reports that the shortest gestation period of 582 mares was 287, the longest 419, and the average, 330 days.

Only the quick-maturing draft filly should under any circumstances be bred as a 2-year-old; all others when past 3 years. If the desire is to improve the strain of horses, one should not attempt to breed even the draft filly at 2 years of age, but when market draft horses are wanted it may prove economical and will not injure the filly to any noticeable degree if she is well-grown for her age and is properly fed and cared for.

Shortly before foaling the grain allowance should be decreased and laxative food more freely used, since it is advisable to keep the bowels rather loose, When wax forms on the mare's teats, or dugs, the foal may be expected in 3 to 4 days. To avoid infection which may cause navel and joint disease, the stall should be thoroly disinfected before the foal is born. Alexander[5] advises removing all litter, scraping the floor, and scrubbing it and the walls with a good disinfectant. The ceiling should be cleaned, and freshly made whitewash, to each gallon of which has been added one-third pound of chlorid of lime, applied to both walls and ceiling. The floor should be covered with fresh, clean straw, as free as possible from chaff and dust, and all manure removed as soon as dropped.

As foaling time approaches, the mare should be watched so as to render assistance, if necessary, yet she must not know that anyone is on guard,

[3] Catalog, 1905. [4] Farmers' Cyc., Johnson, p. 562. [5] Wis. Cir. 13.

for often a mare will not give birth to her foal when persons are present, if she can delay it. The mare should be given a half bucket of water before foaling, and when on her feet again she will need a drink of water or, better, of gruel made from half a pound of fine oatmeal in half a bucket of lukewarm water. A light feed of bran is good for the first meal, and this may be followed by oats, or by equal parts, by bulk, of corn and bran. After foaling the mare should be confined for a few days, her ration being simple and not too abundant. With favorable conditions, after 4 or 5 days she may be turned to pasture, and in about 2 weeks, or even before if work is urgent and the mare has fully recovered, she may go back to light work, for a part of the day at least.

516. Fall foaling.—Altho the natural and customary foaling time is in the spring, where the mare must do a hard season's work or when she does not get in foal from spring service, she may be bred to foal in the fall.

517. The foal.—It is of the highest importance in horse rearing that the foal start life in full health and vigor, and to this end it should, immediately after birth, take a good draft of the colostrum, or first milk, of the dam, which possesses regulating properties that tend to relieve the alimentary tract of fecal matter collected therein before birth. (**115**) If this result is not accomplished naturally, a gentle purgative of castor oil or a rectal injection is necessary. On account of the great danger from navel and joint disease, the navel cord should receive attention immediately after birth, and the stump be carefully disinfected. To prevent germ infection of the intestinal tract of the foal, which causes scours, it is well to wash the udder of the mare with a lukewarm 2 per ct. solution of coal-tar disinfectant and then rinse it off with warm water before allowing the foal its first meal. The tail and hind parts of the mare should likewise be washed once a day for the first week.

Some dams, more frequently those with their first foal and those too hard-worked, fail to supply the proper amount of nourishment, and the young languish. In such cases the mare should be provided with food which will stimulate the milk flow. Good pasture grass is, of course, the best, but in its absence concentrates should be given in the shape of oats, rolled barley, wheat bran, etc., with an equal weight of corn. Sometimes the foal suffers from an over-supply of nourishment, or because the milk is too rich, and the indigestion resulting may terminate in diarrhea. In such cases the dam's ration should be reduced and some of her milk drawn, remembering always that the last portion carries the most fat, which is usually the disturbing element.

518. Weight and gains of foals.—Allen[6] found from the records for 1,071 trotting-bred foals that the weight of the fillies at birth ranged from 74 to 144 lbs., averaging 109 lbs., while the males weighed from 66 to 152 lbs., averaging 111 lbs. The average birth weight was 110 lbs. During the first year they gained 534 lbs., or nearly 5 times their birth

[6] Allen Farm Catalog, 1905.

weight. For the second year the average gain was 264 lbs., the third, 118 lbs., and the fourth, 76 lbs., bringing the total at the end of 4 full years up to 1,102 lbs. These colts made more than half their growth during the first year of their life.

Hooper of the Kentucky Station[7] reports that Thoroughbred foals at the "Nursery Stud," Lexington, Kentucky, made the growth and gains in weight shown in the following table. The data for both colts and fillies are the average for 10 head. They were foaled from the latter part of February to the end of April.

Growth of Thoroughbred foals

	Average for 10 colts				Average for 10 fillies			
	Height		Heart girth	Weight	Height		Heart girth	Weight
	Hands	Inches	Inches	Lbs.	Hands	Inches	Inches	Lbs.
Birth	10	1¼	33¾	...	10	¾	33	...
Nov. 1	13	2	55½	571	13	2½	56½	557
Dec. 1	13	3½	58	629	13	3½	57½	609
Jan. 1	14	¼	59	668	14	...	58½	653
Feb. 1	14	1¼	60¼	703	14	¾	60½	683
Mar. 1	14	2	61¾	739	14	1½	61½	710
Apr. 1	14	2	63½	780	14	2	62¾	760
May 1	14	3½	64½	833	14	2¾	63¾	801
June 1	14	3½	64¾	863	14	3¾	65¼	848
July 1	15	¾	65¾	922	14	3¾	65½	904

It will be noted that when about 15 months old the colts averaged 922 lbs. in weight, and the fillies 904 lbs. On the average the monthly increase in height was 1.3 inches and in heart girth, 2.1 inches.

Data on the gains of 35 draft colts, from high-grade or pure-bred mares averaging 1,700 lbs. and sired by stallions averaging nearly 2,000 lbs., have been compiled by the Breeder's Gazette.[8] The birth weights of the foals were not reported, but the weights and gains after the first month were as follows:

Weights and gains of draft foals from birth to two years

Period	Wt. at end Lbs.	Daily gain Lbs.	Period	Wt. at end Lbs.	Daily gain Lbs.
Birth—1 month	345	...	6— 7 months	890	2.0
1—2 months	465	4.0	7— 8 months	960	2.3
2—3 months	570	3.5	8—10 months	1,085	2.1
3—4 months	675	3.5	10—12 months	1,170	1.4
4—5 months	760	2.8	12—18 months	1,445	1.5
5—6 months	830	2.3	18—24 months	1,590	0.8

These colts were well fed with the intention of making them as large as their parents. Some were given grain and cow's milk before weaning, while others had only hay and good pasture until after weaning. The figures show that at 12 months a well-fed draft colt weighs more than half as much, and at 24 months about three-fourths as much as at maturity. The daily gains were by far the largest before weaning and

[7] The Thoroughbred Record, July 9, 1921. [8] Breeder's Gaz., 59, 1911, p. 1223.

gradually decreased as the colts matured. If the foal is to reach full development, it must not be stunted during the first year of its life.

519. Feeding the foal.—By placing the feed box low, when 3 or 4 weeks old the foal will begin nibbling from the mother's supply and will soon acquire a taste for grain. The earlier the foals so learn to eat, the more independent they become, and the mare will then be able to do more work. Crushed oats or oatmeal, with bran, are excellent feeds, as is a mixture of 4 parts of crushed corn, 3 of bran, and 1 of linseed meal. Colts should be given good clover, alfalfa, or other legume hay as soon as they will eat it, and all the clean, pure water they want. Watchfulness should always detect the first appearance of ailment. Diarrhea brought on by over-feeding or exposure must be checked by giving parched flour, rice-meal gruel, or boiled milk; and constipation, the other common evil, may be relieved by castor oil and injections of warm water, flaxseed tea, sweet oil, etc., administered preferably with a fountain syringe having a small hard rubber nozzle. Harm may be done by injecting a large quantity of strong soapy warm water with an ordinary "horse" syringe. In all cases of derangement the food for both dam and foal should at once be lessened, since nothing aids nature more at such times than reducing the work of the digestive tract.

When the mare is worked, the colt should be left in a cool, dark stall during the day, where he will be safe and not be bothered by flies, rather than allowed to follow the dam about the field. The mare must be brought to the barn to suckle the colt in the middle of the forenoon and afternoon. The colt should not be allowed to drain the udder while the mare is very warm, as indigestion and scours are apt to follow. Allow the mare to cool off, and perhaps draw some of the milk by hand before turning her into the stall with the foal. Brood mares at work and nursing strong foals should be heavily fed to sustain a good milk flow. If the mare is worked during the day, it is well to turn both dam and foal onto grass pasture at night, and in addition feed a liberal allowance of grain. (147)

When dams and foals are running at pasture, a creep should be constructed whereby the foals can have access to a separate supply of grain. Build a pen in the pasture near where the horses are inclined to loiter, making it so high that the mares will not try to jump it, and with sufficient space from the ground to the bottom rail to allow the foals to pass under. Put in a handy gate or bars, then an ample feed trough. After the mares and foals have eaten together within the pen a few times, the foals will visit the place regularly after their dams are shut out. To induce the dams to loiter about, it is well to keep a large lump of rock salt near by and occasionally give a feed of oats at the pen. If flies torture the foal, it is better to keep the mare and foal in a darkened stall during the day and turn to pasture only at night.

520. Mare's milk.—Mare's milk is white or bluish in color with an aromatic, sweetish, slightly bitter taste. As is shown in Appendix Table I,

it is more watery than average cow's milk, and while it contains more sugar, it is decidedly poorer in casein, albumin, and ash. (115)

In certain districts of Europe and Asia mares are used to some extent for milk production. According to Fleishmann,[9] Tartarian mares sometimes remain in milk for 2 years, producing 440 to 490 lbs. of milk annually beyond the requirements of their foals. Vieth[10] reports that good Russian milking mares, when milked 5 times a day, as is the practice, yield 4 to 5 quarts of milk daily.

The foal may be taught to drink cow's milk by pouring it upon meal. The young thing readily eats the moistened feed, and by tipping the pan it soon learns to drink the milk. At the Iowa Station[11] Wilson and Curtiss successfully fed whole milk, and later separator skim milk to imported Percheron, Shire, and French-Coach weanling fillies shortly after their arrival from abroad and while out of condition. In changing from whole to separator skim milk the amount was reduced for a day or two to prevent scouring. Ten lbs. of separator skim milk was found equal to 1 lb. of grain.

521. Raising the orphan.—If the mare dies or has no milk the foal may, with proper care, be raised on cow's milk. (265-6) Choose the milk from a fresh cow, if possible, and preferably from one giving milk low in fat. To a tablespoonful of sugar add warm water to dissolve, then 3 to 5 tablespoonfuls of lime water, which tends to correct digestive troubles, and enough fresh milk to make a pint. Feed about one-fourth pint every hour for the first few days, always warming to blood heat. A satisfactory method of feeding the foal is to use an ordinary nursing bottle with a large nipple. Whatever utensil is used, it should be thoroly cleansed and scalded before each meal. Such feeding means much bother, but many foals have been killed by neglect of these important details. As the foal grows, the amount of milk may be gradually increased, the period between feedings lengthened, and whole milk substituted. After a few days 6 feedings a day will suffice and later only 4. At 3 to 4 weeks of age the use of sugar may be stopped, but it is well to continue the lime water. In 5 or 6 weeks sweet skim milk may be gradually substituted for whole milk, and after 3 months the colt may be given all it will drink 3 times a day. If allowed to suck the attendant's fingers the foal will soon learn to drink from a pail. The bowels should move freely, but if scours occur at any time Alexander[12] advises giving 2 to 4 tablespoonfuls of a mixture of sweet oil and pure castor oil shaken up in milk, and stopping the feeding of milk for 2 or 3 meals, allowing instead only sweetened warm water with lime water added. At the earliest possible age the foal should be fed solid food, such as oat meal, crushed oats, corn, bran, and a little oil meal and legume hay. For exercise let the orphan run in a lot or grass paddock.

522. Weaning.—At from 4 to 6 months of age, depending on conditions, the foal should be weaned. When the mare is bred soon after foaling, or

[9]Lehrb. Milchwirtschaft, 1901, p. 65.
[10]Landw. Vers. Stat., 31, 1885, p. 354.
[11]Iowa Bul. 18.
[12]Wis. Cir. 13.

WELL-BRED MARES AND FOALS ON A CORN-BELT FARM

Only about 60 per ct. of the mares that are bred each year produce living foals. The greater part of this enormous loss can be prevented by proper feed, care, and management.

PURE-BRED PERCHERON FILLIES AT THE ILLINOIS STATION

These fillies were fed equal parts of corn and oats with pasture in summer and with alfalfa hay and a little oat straw in winter. The total cost of feed per head from weaning to 2 years old was $103.59. (Page 326).

THREE-YEAR-OLD COLTS AT NEW YORK (CORNELL) STATION

The cost of raising these pure-bred colts to 3 years of age was only $158.34 a head, without allowing any credit for the manure.

A Creep for Feeding Foals on Pasture

For foals on pasture with their dams, a creep should be provided, such as this, where the foals can have access to a separate supply of grain or other concentrates.

Mules at Work on a Corn-belt Farm

The mule is the chief work animal on southern farms and is increasing in popularity in the corn belt. From 1910 to 1922 the number of mules on farms in the United States increased 29.1 per ct.

if for any reason the dam and foal are not doing well, it is best to wean comparatively early. On the other hand, if the mother has a good milk flow, and her services are not needed, the foal may well be allowed to suckle 6 months. If the foal has been fed increasing quantities of grain as it developed, the weaning process will not be difficult, for the quantity of milk consumed will have been gradually decreased. Complete separation will then cause little, if any, setback to either dam or foal. In parting the dam and foal, keep them well separated, else all must be done over again. Weanlings should be placed in quarters where they can not injure themselves while fretting for their mothers. At weaning the grain ration of the mare should be reduced till she is dried off. When the udder becomes so full as to cause uneasiness, part, but not all, of the milk should be drawn.

The education of the colt should not be postponed until it is sought to "break" him as a 3-year-old, and then attempt to bring the independent animal under man's guidance all at once. The young foal should be taught to lead at the halter, stand tied in the stall, and display proper stable manners.

523. After weaning.—We have seen that the foal makes more than half its entire growth during the first year, and that if stunted during this time it will never fully recover. (**518**) Good bone and muscle are of prime importance with the horse, and feeds which tend to produce these should be chosen. (**118-20**) Nothing is superior to bluegrass or other good pasture, with oats as the grain. Among the concentrates, wheat bran, linseed meal, buckwheat middlings, wheat middlings, soybeans, cowpeas, and Canada field peas are rich in nitrogenous matter, which goes to build muscle, and in phosphorus, a prime requisite of the skeleton. All the legume hays—alfalfa, clover, cowpea, etc.—are rich in lime, the principal mineral component of the bones. A combination of such concentrates and roughages as these should furnish abundant bone-and muscle-building material. When properly balanced by nitrogenous feeds, corn, barley, kafir, milo, or emmer may be used as part of the ration. When fed large amounts of alfalfa hay, colts will relish a little timothy or prairie hay, straw, or corn fodder occasionally. If maximum growth is desired, it will be necessary to feed some grain even on good pasture. A young horse that is not developing the proper skeleton may be fed substances especially rich in phosphorus and lime, such as 2 or 3 ounces daily of tankage containing ground bone, or 1 ounce daily of ground bone, ground rock phosphate (floats), or precipitated calcium phosphate. These recommendations are based on the results obtained with other farm animals.

In the case of high-grade and pure-bred draft foals, it is especially necessary that the supply of feed be liberal, for the price of the draft horse depends largely on the size. Cochel and Severson[13] fed a lot of 10 draft colts during 2 winters and the intervening summer to secure data on the feed required by draft foals. Most of the grain was a

[13] Penn. Bul. 122.

mixture of 5 or 6 parts of shelled corn, 3 of oats, 2 of bran, and 1 of linseed meal. On account of limited pasture an unusually large allowance of grain was necessary during the summer. No effort was made to secure extreme weight, the colts being kept merely in good growing condition. The average gain per head was 727 lbs., the fillies averaging 1,317 lbs. in weight as 2-year-olds.

During the first winter the average daily gain was 1.45 lbs. and the average ration was 5.8 lbs. of the grain mixture with 11.8 lbs. of hay or 7.4 lbs. of hay and 8.2 lbs. corn silage as roughage. During the summer they were fed on the average 6.7 lbs. grain and 6.0 lbs. hay per day in addition to pasture, the average daily gain being 1.34 lbs. The second winter the average ration was 9.2 lbs. grain and 17.1 lbs. hay, and they gained on the average 1.30 lbs. daily. At 1912 prices the cost of feed was $53.97 per head for the first year after weaning, and $92.96 for the entire 18 months.

Various rations for raising draft colts have been tested in 3 trials by Edmonds and Kammlade at the Illinois Station.[14] In these trials purebred draft fillies have been fed from weaning time until they were about 2 years old. In one trial a mixture of 40 parts of corn, 40 of oats, and 20 of bran was compared with equal parts of corn and oats. Alfalfa hay was fed the first winter, and alfalfa hay and a little oat straw the second. In summer the fillies were allowed 1 acre of pasture a head and were given concentrates in addition. Both lots gained on the average 1.4 lbs. a head daily. When 2 years old their average weight was 1,544 lbs. and their average height, 15 hands 3 1/4 inches. Lot I required on the average 4,404 lbs. concentrates, 5,762 lbs. alfalfa hay, and 462 lbs. oat straw for 518 days, the feed per head costing $109.04 with corn at 56 cents a bushel and other feeds in proportion. Lot II required slightly less feed, and the cost was only $103.59.

In another trial a mixture of 75 parts oats and 25 parts bran was compared with the same proportions of corn and bran. The amount of concentrates was reduced to the minimum needed for good growth. Both lots gained 1.3 lbs. a head daily, but the fillies fed oats and bran required on the average 6.4 lbs. per head daily, which was 1.0 lb. more than those fed corn and bran needed for the same gains. For a 490-day period the latter lot consumed per head only 2,647 lbs. corn and bran, 3,226 lbs. alfalfa hay, and 2,490 lbs. oat hay, the total feed cost per head being but $74.21. Tho less feed was required when corn was the chief grain fed and the cost was less, it was the opinion that the quality of the fillies was a trifle better when more oats were fed. The mixture of oats and bran proved most satisfactory, disregarding the cost.

524. Substitutes for oats.—To determine whether good draft colts could be grown without oats McCampbell fed 2 lots of high grade draft colts at the Kansas Station[15] from weaning until they were two and one-half years old. The first lot consumed during this time per head

[14]Ill. Buls. 192, 235. [15]Kan. Cir. 57.

5,198 lbs. oats, 4,673 lbs. alfalfa hay, 528 lbs. corn stover, and 576 lbs. straw, with rather scant pasture in summer. They gained .96 lb. per head daily on this oats-alfalfa hay ration. The other lot, fed no oats, each consumed 3,639 lbs. corn, 1,300 lbs. bran, and 260 lbs. linseed meal, with the same amounts of roughage as the first lot. Their gain was slightly greater, being 1.02 lbs. per head daily, showing this concentrate mixture to be entirely satisfactory as a substitute for oats. The entire cost for feed and other expenses for the 2 years, including labor and veterinary services, was $128.84 per colt for the first lot and $117.90 for the lot fed no oats. Adding to this the sum of $50.00, which was estimated as the cost of a colt at weaning time from mares used for farm work, the total cost of a colt at two and one-half years was $178.84 and $167.90 for the respective lots under pre-war conditions. At the close of the trial the station was offered $200.00 a head for the colts.

525. Feeding no grain after the first winter.—That colts may make fair gains when fed no grain after the first winter is shown in a trial by Snyder[16] at the North Platte Station, Nebraska, in which 3 lots of foals were fed for 3 years after weaning. During the first winter all lots were fed 4 lbs. grain per head daily. Lot I, fed alfalfa hay in winter and grazed on alfalfa pasture in summer, made an average gain of 678 lbs. Lot II, also fed alfalfa hay in winter, but grazed on native pasture in summer, gained 611 lbs. per head. Lot III, fed prairie and sorghum hay in winter, with native pasture in summer, gained only 540 lbs. per head. Snyder concluded that it paid to feed alfalfa hay in winter instead of prairie or sorghum hay but under his conditions it did not pay to pasture alfalfa in summer.

526. Cost of raising horses.—The data presented previously show the amount of feed consumed by heavy drafts colts from weaning to 2 or 2 1/2 years of age. From this the feed cost may readily be found, taking feeds at local prices. To this must be added the cost of the colt at weaning and the other expenses in addition to the feed cost. Using the Illinois and Kansas data and taking 1921 prices, it will be found that the total gross cost will be $150 to $200. From this should be deducted the value of the manure produced. At a very conservative estimate, this should be worth $30 on most farms. This would make the net cost of these heavy draft colts from $120 to $170 at 2 to 2 1/2 years of age. While there should be a reasonable profit in raising draft colts of good breeding, little or none can be expected from "farm chunks" under present conditions.

In investigations from 1909 to 1918, with a total of 66 colts, chiefly pure bred and high-grade Percherons, Harper of the New York (Cornell) Station[16a] found that up to weaning they consumed 180 lbs. of concentrates on the average; from that time to 1 year of age, 1,214 lbs. concentrates and 1,594 lbs. hay; during the second year 1,507 lbs. concentrates and 2,525 lbs. hay; and during the third year 1,898 lbs. con-

[16]Nebr. Bul. 130.

[16a]N. Y. (Cornell) Bul. 403.

centrates and 2,790 lbs. hay; making a total of 4,746 lbs. concentrates and 6,804 lbs. of hay eaten per head up to 3 years of age. The average birth weight of the colts was 116 lbs. and their average weight when 3 years old, 1,270 lbs.

The average cost of raising these colts to 3 years of age was as follows: Feed, $123.64, with concentrates at $28 a ton and hay at $12 a ton (cost of concentrates, $67.18; hay, $41.46; pasture, $15.00); care and shelter, $20.00; service fee, $15.00; inconvenience, and time lost by mare, $10.00; mortality risk and insurance, $16.85; veterinary service and supplies, $2.00; total gross cost, $187.49. Deducting half the cost of the third year ($29.15), as colts commonly earn their keep at two and a half years of age, brought the net cost of the 3-year-old colt to $158.34, with no credit allowed for the value of the manure produced.

The average total cost of raising colts on farms to the age of 3 years, according to estimates received from over 10,000 farmers in various sections of the United States by the Bureau of Statistics, United States Department of Agriculture,[17] was $104.06, under pre-war conditions. If we deduct the value of the work done by the average colt before his third year, the net cost without giving any credit for the manure produced was $96.54, or 70.9 per ct. of the estimated selling price, $136.17. This cost was considerably less than the cost of raising the colts in the Illinois, Pennsylvania, and Kansas trials, owing to the fact that the colts were undoubtedly mostly not of heavy draft type. The cost in different states varied from $69.50 for New Mexico and $71.59 for Wyoming, to $149.98 for Connecticut and $156.60 for Rhode Island. The average cost was distributed as follows:

Cost of raising colts to 3 years of age under pre-war conditions

	First year Dollars	Second year Dollars	Third year Dollars	Total cost Dollars
Service fee	12.95	....	....	12.95
Time lost by brood mare	10.06	....	....	10.06
Breaking to halter	2.22	....	....	2.22
Care and shelter	4.98	5.36	6.35	16.69
Cost of grain fed	4.98	7.14	9.56	21.68
Cost of hay fed	4.14	6.61	8.48	19.23
Cost of pasture	2.56	5.41	6.21	14.18
Veterinary and miscellaneous	.....	....	....	7.05
				$104.06

II. The Stallion

527. Importance of exercise.—In the care of the stallion nothing so vital to his well being is more generally neglected than proper exercise. (111) Often his time is spent in idleness, in a poorly-ventilated box stall, away from his kind. Under such conditions, it is no wonder that he may contract vices, become unruly or even vicious, and get only a small percent-

[17] Gay, Productive Horse Husbandry.

age of colts. The best exercise is honest work, and there is no better advertisement of a stallion than letting him be seen at work on the farm or road. Even during the breeding season, a half day's work each day is beneficial. Manifestly, judgment must be used in accustoming "soft" stallions to continued hard work. When real work is impossible, he should be exercised on the road each day. The draft horse under ordinary circumstances should travel at least 5 miles a day, while the light horse may jog and trot 6 miles or more.

528. Feeding the stallion.—The ration of the stallion should consist of first class, wholesome feeds, supplying ample protein and mineral matter for thrift and vigor. The choice of feeding stuffs will depend on the particular locality, the same principles applying as in the case of the work horse. A few combinations given by McCampbell[18] as satisfactory in practice may prove suggestive.

1. Oats; timothy or prairie hay.
2. Oats, 4; corn, 6; and bran, 3 parts by weight; timothy or prairie hay.
3. Oats, 4; corn, 6; linseed meal, 1 part; timothy or prairie hay.
4. Corn, 7; bran, 3; linseed meal, 1 part; timothy or prairie hay.
5. Corn; alfalfa hay 1/3 and prairie hay 2/3.

No specific directions can be given as to the total amount of feed required, since this depends on the exercise the animal gets and whether he is a "hard" or "easy" keeper. A safe rule is to keep the stallion in good flesh, but not "hog fat," for this will injure his breeding powers. Most horsemen advise that in the breeding season he be kept gaining just a bit, rather than allowed to run down in flesh. While some recommend feeding 3 times a day, 4 is preferred by others. In either case no more should be fed than will be promptly cleaned up.

529. General hints.—On the care of the stallion, Sanders[19] writes, "Anything that adds to the health, strength, and vigor of the horse will increase his virility or sexual power, simply because the sexual organs will partake of the general tone of the system; and on the contrary, whatever tends to impair the health and vigor of the general system will have a deleterious effect upon the sexual organs." The stall should be kept clean, well lighted, and well ventilated. As a horse likes companionship, it is well to have the stallion's stall near those of other horses. He should be regularly and thoroly groomed, and frequent attention should be given his feet. The idea that drugs, nostrums, or stock foods are necessary to increase the ability of the horse to get foals is sheer nonsense. The most successful grooms utilize only good food, carefully and regularly administered. It is important to conserve the energies of the stallion by regulation of the services, as otherwise many horses are injured.

[18]Kan. Bul. 186.
[19]Horse Breeding, pp. 144–146.

III. Work Horse and Mule; Fattening and Fitting Draft Horses

530. The work horse.—The regularity in work, feeding, and rest usually bring long years of usefulness to the work horse. The general principles which govern the production of work by the horse and the various feeds employed for his maintenance have been discussed in detail in the preceding chapters. The ration to be fed will depend upon the size of the animal and the nature and severity of the work, as has been shown before. (**449-56**)

As a rule the total allowance of grain and hay should be from 2 to 2.5 lbs. per 100 lbs. of horse. Sufficient grain should be fed to keep each horse in the desired condition. Some horses are "easy" and others "hard keepers", requiring considerably more grain for the same amount of work. On the average, horses at medium to hard work will need 0.7 to 1.4 lbs. of grain per 100 lbs. live weight. The morning meal should be light, not over one-third the daily allowance of grain, with a small allowance of hay. Most horsemen believe that some grain should be fed at noon, tho the mid-day meal is sometimes omitted, especially with horses on the street all day. Many feed one-third the concentrates at morning, noon, and night, respectively. It is not necessary to feed any roughage at noon. Most of it should be fed at night. Some prefer to feed a larger allowance of concentrates also at this time.

To avoid digestive troubles and possible deaths from azoturia, it is imperative that the allowance of concentrates for horses at hard work should always be decreased on idle days. A safe rule is to feed on idle days not over about 70 per ct. the usual weight of concentrates, using in place of all grain a mixture of two-thirds grain and one-third bran. Others feed a small allowance of grain at noon with only a bran mash both night and morning.

On coming to the stable at noon, the work horse should have a drink of fresh, cool water, care being taken, if he is warm, that he does not drink too rapidly or too much. Before going to work he should be watered again. (**464**) Many good horsemen remove the harness so the horse can eat his meal in comfort and rest easily. If possible, an hour should be given for the mid-day meal. When the horse comes in after the day's labor, after giving him a drink, unharness at once, and when the sweat has dried brush him well. (**468-70**)

Many rations for work horses have been discussed in Chapter XIX, and the principles which should be followed in computing rations for them have been stated in Chapter XVIII. As an additional guide in working out economical rations suited to one's own conditions, the following sample rations are given for 1,000-pound horses which are idle, and at light, medium, and hard work. All these rations meet the requirements according to the Morrison feeding standards, and should prove satisfactory in practice. (**454-5**) With horses of other weights, the

rations should be increased or decreased accordingly. For example, the 1,500-pound horse will take about 1.5 times as much feed as one weighing 1,000 lbs.

The following will illustrate the substitutions which may be made in these rations. Still others are discussed in the preceding chapter.

Hay from other grasses may be substituted for timothy hay, usually pound for pound. The legume hay may be alfalfa, red clover, alsike clover, sweet clover, soybean, cowpea, lespedeza, etc. Fodder and stover from the sorghums may replace corn fodder and stover. Crushed or ground barley may be substituted for oats, one-tenth less being fed. Crushed or ground grain sorghums may be fed in place of corn, 5 to 10 per ct. more being required. Cottonseed meal may replace linseed meal. Wheat bran, gluten feed, peanut meal, and other protein-rich feeds may be substituted for linseed meal, the amount being increased proportionally in the case of bran, gluten feed, or other supplements which are lower in protein than linseed meal. For horses at work straw had best be chopped and mixed with the concentrates.

Example rations for various classes of work horses

1,000-lb. horse at hard work

1. Timothy hay, 11 lbs.
   Oats, 12.5 lbs.
2. Timothy hay, 11 lbs.
   Corn, 8.5 lbs.
   Linseed meal, 2 lbs.
3. Legume hay, 11 lbs.
   Corn, 10 lbs.
4. Red clover hay, 6 lbs.
   Timothy hay, 5 lbs.
   Corn, 9 lbs.
   Linseed meal, 1 lb.
5. Alfalfa hay, 6 lbs.
   Timothy hay, 5 lbs.
   Corn, 10 lbs.
6. Shredded corn fodder, 6 lbs.
   Legume hay, 5 lbs.
   Oats, 12.0 lbs.
7. Oat or barley straw, chopped, 3 lbs.
   Legume hay, 8 lbs.
   Oats, 12.0 lbs.

1,000-lb. horse at medium work

1. Timothy hay, 12 lbs.
   Oats, 9 lbs.
2. Timothy hay, 12 lbs.
   Corn, 5.75 lbs.
   Linseed meal, 1.75 lbs.
3. Legume hay, 12 lbs.
   Corn, 7 lbs.
4. Red clover hay, 6 lbs.
   Timothy hay, 6 lbs.
   Corn, 6.5 lbs.
   Linseed meal, 0.75 lbs.
5. Alfalfa hay, 6 lbs.
   Timothy hay, 6 lbs.
   Corn, 7 lbs.
6. Shredded corn fodder, 6 lbs.
   Legume hay, 5 lbs.
   Oats, 9 lbs.
7. Oat or barley straw, chopped, 4 lbs.
   Legume hay, 8 lbs.
   Oats, 9 lbs.

Example rations for various classes of work horses—continued

1,000-lb. horse at light work

1. Timothy hay, 14 lbs.
   Oats, 4 lbs.
   Linseed meal, 0.75 lb.
2. Timothy hay, 14 lbs.
   Corn, 2.5 lbs.
   Linseed meal, 1.5 lbs.
3. Legume hay, 14 lbs.
   Corn, 3.5 lbs.
4. Red clover hay, 7 lbs.
   Timothy hay, 7 lbs.
   Corn, 3 lbs.
   Linseed meal, 0.5 lb.
5. Alfalfa hay, 7 lbs.
   Timothy hay, 7 lbs.
   Corn, 3.5 lbs.
6. Shredded corn fodder, 6 lbs.
   Legume hay, 7 lbs.
   Oats, 4.75 lbs.
7. Oat or barley straw, 4 lbs.
   Legume hay, 10 lbs.
   Oats, 4.75 lbs.

1,000-lb. idle horse

1. Timothy hay, 15 lbs.
   Linseed meal, 1.25 lbs.
2. Legume hay, 16 lbs.
3. Timothy hay, 8 lbs.
   Red clover hay, 8 lbs.
4. Corn stover, 9 lbs.
   Legume hay, 8 lbs.
5. Corn silage, 13 lbs.
   Legume hay, 8 lbs.
   Oat or barley straw, 4 lbs.
6. Oat or barley straw, 6 lbs.
   Legume hay, 10 lbs.
   Corn, 1 lb.
7. Kafir stover, 7 lbs.
   Alfalfa hay, 8 lbs.
8. Johnson grass hay, 8 lbs.
   Cowpea hay, 8 lbs.

531. Wintering the farm horse.—It has already been shown that the farm horse when idle during the winter may be economically wintered wholly, or in part, on roughages. (**448**) Rather than keep the idle horse too closely confined at such times, it is preferable to turn him out daily into a lot, protected from the wind. (**466**) At shedding time, feed some grain even if the horses are idle. Light grain feeding, together with light work, should begin a few weeks before the spring work starts, for horses are soft after a winter of idleness.

532. The mule.—It is often stated that mules require less feed than horses to do a given amount of work. Some evidence in this direction is furnished by the investigation of the cost of horse and mule labor in Missouri, reviewed in the previous chapter. (**513**) On the other hand, others assert that there is no foundation for this statement. At 3 years of age, when shedding his milk teeth, the mule is especially susceptible to digestive disorders. Otherwise, he is an excellent feeder, as a rule being more sensible in eating and less likely to gorge himself than the horse, and hence less subject to colic or founder. Indeed, mules are often fed at troughs, like cattle, and allowed to eat all they desire. The mule is not fastidious in his taste and consumes roughages which the horse will refuse. He also endures hot weather better, and, because of the peculiar shape of the foot and its thick, strong wall and sole, is less subject than

the horse to foot lameness. However, the lack of weight and the small size of his foot somewhat unfit the mule for heavy draft work in the city, as he does not get a good hold on the pavements.

Tho the mule will endure more neglect than the horse, good care and feed will prove profitable. For feeding the mule the same feeds are available as in the case of the horse, and the same principles apply in suiting the feed to the size of the animal and the severity of the work performed.

533. Fattening horses.—As the large markets demand draft horses in high flesh, in certain districts their fattening has become an important industry. The horses are usually purchased in the fall after farm work is over and gradually accustomed to a heavy grain ration, getting all they will clean up when on full feed. At this time some of the heaviest feeders will consume nearly twice as much as when at hard work, or about 2 lbs. of grain for every 100 lbs. live weight. The chief concentrates used are corn and oats, often with moderate allowances of such protein-rich feeds as wheat bran, linseed meal, or cottonseed meal added to balance the ration. Clover or alfalfa hay is commonly fed, for these hays are much superior to timothy hay for this purpose. In addition, silage of good quality may be advantageously fed. At the Illinois Station[20] a ration of 8.6 lbs. corn, 8.6 lbs. oats, 2.4 lbs. wheat bran, 0.4 lb. oil meal, and 13.7 lbs. clover hay gave excellent results in fattening horses. A most successful ration for 1,450-lb. horses at the Pennsylvania Station[21] was 12.3 lbs. shelled corn, 1.4 lbs. cottonseed meal, 16.9 lbs. corn silage, and 10.5 lbs. mixed hay. Horses thus fattened require about the same amount of feed as fattening cattle for 100 lbs. gain in weight.

Formerly the horses were usually allowed no exercise, great care then being necessary to avoid digestive troubles and to keep their legs from becoming stocked. Now many feeders allow the horses to run in paddocks. Due to the forced feeding, surprising gains are often secured. Instances are reported where horses have gained 4 lbs. or even more per head daily for periods of about 2 months. While at present horses must be thus fattened to bring top prices, such rapid and excessive fattening is of little benefit and may even be injurious. When put to hard work, the horse quickly loses much of the soft flesh gained by such forcing.

534. Hints on fattening horses.—Altho some feed the horses 5 or 6 times a day, others secure just as good results with 3 feeds. Water should be supplied freely at least twice a day. Usually no feed is administered between 5 or 6 o'clock at night and 6 the next morning. Grooming and blanketing aid in producing a soft, shining coat, which increases the selling price. (**468-9**) It is important to keep mangers and feed boxes clean, and to see that the teeth and feet of the animals are in good condition. (**470-1**)

[20] Obrecht, Ill. Bul. 141.

[21] Cochel, Penn. Bul. 117.

On fattening horses, Cochel[22] writes: "The cost of gains is not the only factor which determines the profit or loss from the operation. Market values fluctuate quite widely during the time necessary for feeding, hence there may be considerable profit or loss due entirely to this factor. Horses that are kept in idleness are quite apt to become blemished or injured on account of playfulness in the stable. The risk of sickness is greater than with cattle, sheep, and hogs. Many horses are unable to stand a long period of forced feeding because of constitutional weakness. Good judgment in buying and selling is necessary. All other conditions being equal, a close study of the selection of rations and methods of feeding will determine the success or failure of those who finish horses for market."

535. Fitting for shows.—All show horses should be in good flesh, draft classes especially. The advice above given for fattening horses will apply to fitting draft horses for show, except that they must be exercised daily to keep their muscles in good trim. All show horses should be carefully fed, groomed, and exercised to bring them into proper "bloom." Training also counts for much in the show ring.

IV. Feed and Care of the Light Horse

536. Feeding the carriage and saddle horse.—Style and action are primary requisites with these horses, economy of feeding standing second. Good drivers in this country still assert that the oat-fed horse exhibits mettle as from no other feed. Tho oats easily excel any other single grain or concentrate, there are numerous instances in which a properly combined concentrate mixture has given just as good results, as is shown in the preceding chapter. From 8 to 10 lbs. of oats or their equivalent, divided into 3 feeds, should suffice for concentrates, the evening meal being the largest. In case the horse is at all constipated, a bran mash should be given. The hay is usually fed long, for the carriage horse has ample time for his meals. From 10 to 12 lbs. of hay is a liberal allowance, bringing the total ration within 18 to 22 lbs. The carriage horse must be trim in body, and so cannot consume much bulky food, yet we should not forget that the ration must have volume in order that the digestive functions proceed normally. (107) With this class of horses the feeder must also guard against overfeeding of laxative foods, such as clover and alfalfa hay, or bran. Carriage horses are usually fed too much and exercised irregularly or too little, and mainly for these reasons their period of satisfactory service is often brief. (466) On days when they are not driven, oats should be fed only at noon, with a bran mash morning and evening, no difference being made in the quantity of roughage fed.

537. Feeding the trotter.—The single requisite of speed makes the carrying of every pound of useless body weight, and more especially of feed, a serious matter in the management of the trotting horse. There

[22] Penn. Bul. 117.

is also to be considered the effect of the food on the character of the muscles formed from it, and especially on the nerve and mettle of the horse. All horsemen agree in regarding oats as the one grain suitable for animals where speed is sought regardless of cost of food. While this opinion prevails in this country, we should remember that the Arab horse usually subsists upon barley.

For information on feeding the trotter we can draw from no better source than Hiram Woodruff,[23] whose advice is here condensed.

After weaning, trotting bred colts should be fed about 2 lbs. of oats per day, with an unlimited allowance of hay. As the colt grows older the amount of oats should be increased to 4 lbs. for the yearling, 6 lbs. for the 2-year-old before training, and 8 to 12 lbs. for the colt 2 to 3 years old in training, an unlimited allowance of hay being given all this time.

When going into winter quarters, the feed of the trotter should be reduced fully one-half in order to prevent fattening. A few carrots may be given and a bran mash occasionally, with good clean, sweet hay. Horses whose legs must undergo blistering or firing should have more cooling feed, as mashes and carrots, with less oats, in order to reduce the tendency to feverish, inflammatory symptoms. Care must be taken not to permit the animal to get flabby or washy by too much soft food while undergoing treatment. Horses turned out to the field should be fed oats twice a day, for the exposure to the severity of the weather increases the need of heat-giving food. In the spring when shedding, bran mashes are in order to keep the bowels open, but not flax seed or linseed meal, which have a tendency to relax the system too suddenly and to cause the old hair to come away before the new coat is well started.

With the beginning of the season the feed should be increased to 8 to 10 lbs. of oats daily, in which case the horse wants less hay, but may still have all he will clean up unless he is a glutton. It is necessary to muzzle some horses to prevent their eating the bedding, long before the time for the race. No carrots or corn should now be given, unless it is necessary to induce a light feeder to eat his oats by mixing a handful of corn with them.

During the jogging and after preparation, a bran mash about once a week, depending on the condition of the horse's bowels, will be proper. The trainer must never relax his vigilant observation, or let his judgment sleep. During the fast work, preparatory to the coming trial, the horse will be put upon his largest allowance of strong food. Some will not eat more than 8 or 10 lbs. of oats a day; and it is necessary that such light feeders be not over worked. A good feeder ought to have about 12 to 13 lbs. of oats with a fair amount, say 6 to 8 lbs., of hay. Some will eat 16 lbs. of oats a day.

538. Army horses.—Oats, hay, and straw are the standard feeds used for army horses by the great nations, since they best fill the following rigid requirements: All provender for such purposes must not only be

[23] The Trotting Horse of America, pp. 90-105.

palatable and safe, but also widely known articles of trade, easily collectible in vast quantities, readily inspected, and generally uniform in quality; moreover, they must not be subject to excessive waste or deterioration during storage and transportation.

In the United States army the standard daily allowance for a horse is 14 lbs. of hay and 12 lbs. of oats, corn, or barley, with three and one-third lbs. of straw for bedding (or hay, if straw is not available). For a field artillery horse of the heavy draft type, weighing 1,300 lbs. or over, 17 lbs. of hay and 14 lbs. of grain are allowed, with three and one-third lbs. of straw (or hay) for bedding. For a mule the allowance is 14 lbs. of hay and 9 lbs. of grain, with bedding as before. To each animal 3 lbs. of bran may be issued in lieu of that quantity of grain.

The commanding officer may at his discretion vary the proportions of the components of the ration (1 lb. of grain, 1.5 lbs. of hay, and 2 lbs. of straw being taken as equivalents), and in the field may substitute other recognized articles of forage obtained locally, the variation or substitution not to exceed the money value of the components of the ration at the contract rates in effect at the time of exchange.[24]

In Great Britain the ration is 12 lbs. of hay and 10 to 12 lbs. of oats. Eight lbs. of straw per day is fed horses when at the garrison. In the French army a smaller allowance of hay, 6.6 to 8.5 lbs., is given with an allowance of oats ranging from 10.4 lbs. for light horses in time of peace to 14.7 lbs. for the heavier horses in war time. The German army used cut straw generally in the ration, the roughage ranging from 7.8 lbs. straw and 5.6 lbs. hay in the garrison to only 3.9 lbs. straw and 3.3 lbs. hay when in the field. The allowance of oats ranged from 9.5 lbs. on a light ration in the garrison to 12.6 lbs. on a heavy ration in the field.[25]

With the army horse it is often necessary to use substitutes for the regulation concentrates and roughages. General Carter[26] writes that oats, corn, bran, and sometimes barley, especially in the southwestern states, have been fed as the concentrates to the horses of the United States army. Palay, or unhulled rice, was the main reliance of the cavalry horses in the Philippine Islands during the early days of the insurrection. Pott[27] mentions that a stock bread, made of coarsely ground oats, peas, barley, and linseed, with a little salt added, was employed by the Russian cavalry. The kind of hay fed will vary according to the district. Carter writes that besides the common cultivated grasses, there have been accepted at various times in the United States army, hay from gramma grass, bunch grass, and other wild western grasses, various reed grasses, wild oats, and "pulled" corn fodder.

[24] U. S. Army Regulations, 1917, pp. 212-213.

[25] Langworthy, U. S. Dept. Agr., Office of Expt. Sta., Bul. 125.

[26] Horses, Saddles, and Bridles, 1902, pp. 357-379.

[27] Handb. Ernähr. Futter., I, 1907, p. 329.

CHAPTER XXI

GENERAL PROBLEMS IN DAIRY HUSBANDRY

I. The Dairy Cow as a Producer of Human Food

Among all the animals of the farm, the dairy cow stands unequaled as a producer of human food. She converts the products of the fields, much of which are inedible for man, into human food more economically than any other class of animals. Even more important than this economic superiority, however, is the fact that the food she produces is of inestimable value to the human race. In fact, as a human food, milk is in a class by itself, and the dairy cow has well earned the title, "the foster mother of the human race," bestowed upon her by the late W. D. Hoard of Wisconsin.

539. Merits of milk as a food.—Among the most important recent scientific contributions of the nutrition experts have been the discoveries which have shown an even higher value for milk than had been previously ascribed to it. These investigations, which have been reviewed previously, have shown that the fat of milk is especially rich in the fat-soluble vitamine. Milk is also quite high in the water-soluble vitamine and usually rich in the anti-scorbutic vitamine. All these are absolutely essential to the normal growth and well-being of humans. Therefore a liberal use of milk in the diet is conducive to health. As most of the other foods children eat are low in the fat-soluble vitamine, it is especially necessary that they receive an abundance of milk and dairy products in order to grow vigorously and develop sturdy bodies. (**104**)

In addition to these virtues, milk is rich in protein, and moreover, the protein is of excellent composition to supplement the deficiencies in the proteins of the cereals, so widely used for food. Furthermore, it is rich in mineral matter, and especially in calcium and phosphorus, which are most apt to be lacking in the ordinary foods consumed by man and beast. To complete the list of excellencies, milk also furnishes an abundance of energy-giving nutrients in the fat and the milk sugar. Add to this its palatability and its wide usefulness in rendering more toothsome a host of articles in our diet, and we have indeed a wonderful food. (**115-6**)

Due to this high quality of milk as a food, combined with the economy with which it is produced, the number of dairy cows continues to increase, even tho the number of some other classes of farm animals may grow less.

540. Economy of the dairy cow.—The striking economy with which the dairy cow produces human food, compared with beef cattle, sheep,

and poultry, has already been shown in Chapters V and VI. It has there been pointed out that she returns about 6 times as much edible solids in her milk for each 100 lbs. of digestible nutrients in the food consumed as the steer or sheep yields in its carcass. (131-2) Furthermore, a cow yielding only 8,000 lbs. of milk of average composition produces annually in her milk 56 per ct. more protein, 30 per ct. more non-nitrogenous nutrients (fat and sugar) and 19 per ct. more mineral matter than in the entire body of a 2-year-old fat steer weighing 1,200 lbs. (147)

The economy of food production is even more striking in the case of high-producing cows. Eckles[1] reports that a Holstein cow at the Missouri Station, which yielded 18,405 lbs. of milk in a year, produced during this time 552 lbs. of protein, 618 lbs. of butter fat, 920 lbs. of milk sugar, and 128 lbs. of mineral matter, a total of 2,218 lbs. of edible dry matter of the highest value for human food. The entire body of a 1,250-lb. steer, fed at the same station and analyzed by Trowbridge, contained only 172 lbs. protein, 333 lbs. fat, and 43 lbs. mineral matter, a total of but 548 lbs. This included not only the edible dry lean meat and fat, but also all other parts of the body—hoofs, hair, hide, horns, bones, tendons, and all internal organs. During the year the cow thus produced enough protein to build the bodies of 3 such steers, fat sufficient for nearly 2, and mineral matter enough for 3, besides 920 lbs. of milk sugar, which is as nutritious as the same weight of cane sugar.

Concerning these data Eckles writes: "These figures show the remarkable efficiency of the cow as a producer of human food. It is because of this economical use of food that the dairy cow and not the steer is kept on high-priced land. When land is cheap and feed abundant, the meat-producing animals predominate, but when the land becomes higher in value and feed expensive, the farmer turns to the dairy cow." (200)

In extensive trials covering 9 years Haecker of the Minnesota Station[2] studied the use of feed by cows averaging 910 lbs. in weight and yielding about 24 lbs. of milk daily containing approximately 1 lb. of butter fat. On the average these cows required about 46.5 per ct. of the digestible nutrients in their feed for the maintenance of their bodies, and returned 29.1 per ct. in the milk they produced. The remainder, 24.4 per ct., was used up in the work of producing the milk.

Basing similar computations on the gross energy of the feed consumed (not the energy in the digested nutrients) and the energy in the milk produced, it will be found that cows producing about 1 lb. of butter fat a day will return in their milk about 17 per ct. of the gross energy in their feed. From whatever standpoint we study the matter, it is shown that the dairy cow is unsurpassed in the efficiency with which she converts roughage and concentrates into human food.

[1] Hoard's Dairyman, 41, 1910, p. 122.

[2] Minn. Bul. 140.

541. Dairy vs. beef type.—When in full flow of milk a high producing dairy cow is generally spare and shows an angular, wedge-shaped form, a roomy barrel, spacious hindquarters, and a large udder. This conformation is in strong contrast to that of the low-set, blocky, beef animal, with its compact, rectangular form, and broad, smooth back. These two types are the result of careful breeding with opposite objects in view. The beef animal has been developed to store in its carcass the largest possible amount of meat. On the other hand, for generations the dairy cow has been bred for the primary object of producing large yields of milk and butter fat. The great improvement in productive capacity in each breed of dairy cattle has come thru long-continued selection based on performance at the milk pail. As a result, tho a good dairy cow may put on flesh when she is dry, on freshening the impulse to milk production is so strong that she uses for making milk, all the feed she can eat. Even under liberal feeding she shows little or no tendency to fatten, but rather grows spare and lean as lactation progresses.

To determine whether cows of dairy type were more economical producers than those of the beef type, Haecker of the Minnesota Station[3] divided the Station herd into 4 groups, depending on their type and conformation. The first group, the cows of which were spare, had deep bodies, and were of distinctly dairy type, required only 21.2 lbs. of dry matter in their feed for each pound of butter fat produced. The cows in the second group, which were spare but lacked depth of body, required 25.5 lbs. dry matter per pound of butter fat; the third group, which showed some tendency toward beefiness, required 26.4 lbs. dry matter; and the fourth group, which were decidedly of the beef type, consumed 31.3 lbs. dry matter for each pound of butter fat produced. These beef cows thus required 47 per ct. more feed per pound of butter fat than the cows of good dairy type.

In view of the widely differing nature of the functions of milk and flesh production, it is not surprising that both can not be developed to the highest degree in the same animal. With Smith[4] we must conclude that the most perfect beef cows are not economical milkers, and the best dairy cows are not satisfactory beef makers.

542. Good and poor producers.—That cows of high productive capacity are more economical producers of milk and butter fat than low yielding cows is shown by studies of Carlyle and Woll at the Wisconsin Station.[5] Studying the records of the cows in the station herd during 5 winters, they found that the high-producing cows naturally consumed considerably more feed than the low producers. This was, however, much more than offset by their larger yield. The high producers yielded on the average 26.6 lbs. milk and 1.2 lbs. fat daily, while the low producers averaged but 14.6 lbs. milk and 0.7 lb. fat. The high producers required only 102 lbs. dry matter in their feed for 100 lbs. milk and the low

[3] Minn. Bul. 35.

[4] Profitable Stock Feeding, p. 38.

[5] Wis. Bul. 102.

producers 149 lbs.—thus consuming 46 per ct. more feed for the same amount of product.

Fraser of the Illinois Station[6] reports a cow in the Station herd that in 12 years gave 87,102 lbs. of milk, containing fat sufficient to make 4,318 lbs. of butter. During 3 years a certain cow gave 11,930 lbs. of milk annually, containing 405 lbs. of fat, and returned $42.60 per year over cost of feed. Another with the same feed and care gave in the same time only 3,380 lbs. of milk annually, containing 138 lbs. of fat, and failed by $5.62 per year of paying for her feed.

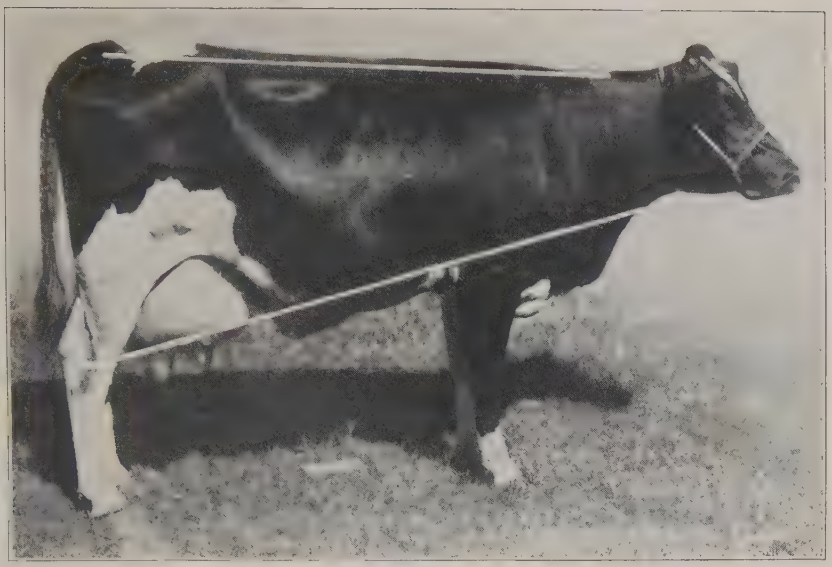
543. Building a herd from scrubs.—An experiment has been carried on for the past 13 years by the Iowa Station[7] to determine whether a good producing and profitable herd could be built up from a foundation of scrub cows, if the proper methods of breeding, feeding, and management were used. Fourteen head of scrub cattle, including mature cows, heifers, and a bull, were purchased in a district of the South where no pure bred bulls had ever been used and where no attention had been paid to the proper breeding or feeding of dairy cattle. These animals were brought to the Station farm and fed and cared for the same as the animals in the pure-bred dairy herd. Most of the females were bred to pure-bred bulls and later the half-blood heifer calves were likewise bred to pure-bred bulls of the same breed.

Kildee, McCandlish, and Gillette report that the average yearly production of the original scrub cows with good feed and care at the Station was only 3,847 lbs. of milk, containing 182 lbs. fat. The daughters of these scrubs out of pure-bred bulls averaged 5,945 lbs. of milk and 262 lbs. fat, an increase of 55 per ct. in milk yield and 44 per ct. in yield of fat. The grand-daughters of the scrub cows, carrying three-fourths of dairy blood, averaged 8,311 lbs. milk and 376 lbs. fat, an increase of 116 per ct. in yield of milk and 106 per ct. in yield of fat over the scrubs. The much greater production of the grades was due not only to a larger yield when in milk but also to the fact that they were much more persistent milkers than the scrubs, whose lactation periods were short. Even more important than the greater yield of milk is the fact that the cost of feed for 100 lbs. milk was 13 per ct. less for the three-quarter bloods, even tho they were only heifers, than for their scrub grand-dams. Not only was the production rapidly improved by grading up, but also just as striking improvements were made in the conformation of the animals. The grades, especially of the second cross, were stamped plainly with the breed characteristics of the pure-bred sire.

Scrub heifers were also raised at the Station out of the scrub cows and the scrub bull. They produced 10 per ct. more milk and 13 per ct. more fat a year than their scrub dams. This small increase, which is strikingly inferior to that produced by the use of pure-bred sires, is due to the fact that the heifers were so fed and cared for as to develop fully

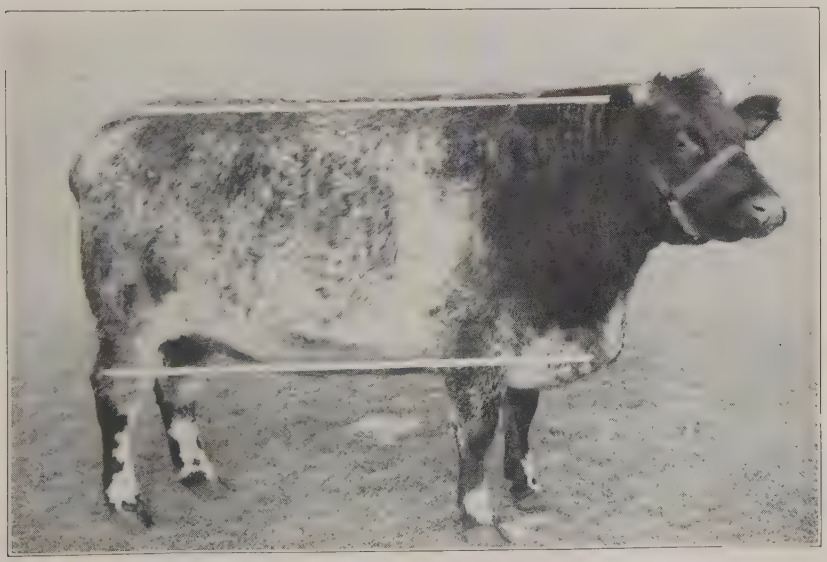
[6] Ill. Cir. 106.

[7] Iowa Buls. 165, 188; Jour. Dairy Science, 4, 1921, pp. 12–23.



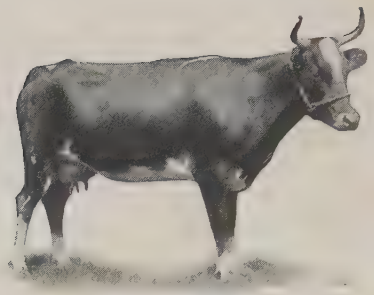
THE DAIRY TYPE, SPARE AND ANGULAR

A high-producing dairy cow is generally spare and angular and shows a wedge-shaped form, viewed from the side, from the front, or from the top of the withers. She has a roomy barrel, spacious hindquarters, and a large, well-shaped udder. (From Wisconsin Station.)



THE BEEF TYPE, WITH COMPACT, RECTANGULAR FORM

The beef type is the result of careful breeding to secure an animal which will store in its body the largest possible amount of high-priced meat. This beef cow has the low-set, blocky, rectangular form, and broad, smooth back of the beef type. (From Wisconsin Station.)



A Scrub Cow Used in the Iowa Experiments

The average annual production of this scrub cow was only 3,312 lbs. of milk and 178 lbs. of butter fat. (From Iowa Station.)

Half-blood Holstein from Scrub Cow and Pure-bred Bull

This cow, a daughter of the scrub above, averaged 6,385 lbs. milk and 305 lbs. fat a year, a remarkable increase over the yield of her scrub dam. (From Iowa Station.)

Grand-daughter of Original Scrub

This heifer, out of the half-blood Holstein cow and a pure-bred Holstein bull, not only shows marked dairy conformation and temperament, but also the characteristic color markings of the breed. (From Iowa Station.)

what little tendency they did have for milk production. Scrubs which came to the station as heifers produced on the average 27 per ct. more milk than those that were mature when they first received good feed and care. The scrubs which were 4 years old when purchased showed less response to good feeding than the heifers. These facts emphasize the necessity of feeding heifers so that they will develop properly.

In these trials the offspring from one of the pure-bred sires used on the scrub cows fell much below the others in productivity. This illustrates the well-known fact that to build up a herd a sire must not only be a pure-bred but also must be prepotent in transmitting dairy qualities and high production.

544. Causes of inefficiency of dairy cows.—Observing a striking difference in the productive capacity of 2 Jersey cows at the Missouri Station, which were raised under the same conditions and were more than half sisters, Eckles and Reed[8] conducted the following trial to find the explanation. During their first 2 lactation periods the better cow had produced 2.8 lbs. of milk and 3.9 lbs. of fat for each pound produced by the other. In the third lactation period the cows calved three days apart and were fed the same feeds supplied in the same proportions, the amount fed being so adjusted that neither cow gained or lost in weight. Neither cow was bred. During the year the better cow consumed 1.75 lbs. of feed for each pound eaten by the other, but produced 2.67 lbs. of milk and 2.77 lbs. fat for each pound yielded by the poorer cow.

When dry, the better cow required more feed to maintain her weight than the poor one. Her greater efficiency was therefore not due to a lower requirement for maintenance. She digested a slightly larger percentage of her ration, but there was far too little difference to explain her much greater economy in production. The real cause of the greater efficiency of the better cow was that she was able to consume and utilize a much larger amount of feed beyond the amount needed to maintain her body, and hence had more feed available for milk production. There was practically no difference in the amount of milk or fat produced by the cows from each 100 lbs. of feed which they ate in addition to the maintenance requirement.

The high producing cow secretes an abundance of milk, on account of her strong inherited impulse to milk production. To replace the nutrients she puts into her product she has a keen appetite and consumes much feed.

545. Weed out unprofitable cows.—Even in the leading dairy states, probably one-fourth or more of the dairy cows fail to pay for their care and feed. The chief reason why such a condition is found now, when the principles of successful selection, feeding, and care of dairy cattle have long been established by scientists and practical dairymen, is that the owners do not know which of their cows fail to yield enough milk to pay for their feed and care. They do not realize that tho the

[8]Mo. Research Bul. 2.

gross income from their herd would be reduced by weeding out the "boarders," their net profits would be materially increased.

Tho good producers are usually of the dairy type and poor producers are not, even experts are often unable to tell from appearance whether a cow is profitable or not. The only reliable way of finding this out is from records of the actual amount of milk and fat she yields. Fortunately, such records may now be easily secured by the use of the milk scales and the Babcock fat test. Knowing the production of each cow and the approximate amount of feed she has consumed in a given period, the dairyman can discard the unprofitable animals, and gradually build up a herd of high producers at small expense by using a bred-for-production sire and keeping all heifer calves from the best cows. By this means the average yield of fat for the herd can be gradually increased year by year, until it is raised to 250 lbs., later to 300 lbs., and then even higher. As good cows sometimes have "off years" in production, animals should not be discarded after a single year's trial if there is good reason to believe they will do better in the future.

546. Keeping records of production.—The most satisfactory way to find out the value of each cow is to weigh and record each milking from every animal. This does not require much work, if a convenient spring balance and handy milk sheets for entry of the records are provided. Such daily individual records make possible the feeding of each cow with the greatest economy, enable the herdsman to detect sickness quickly by the decline in milk flow, and aid in judging the efficiency of the different milkers. Where the weight of each milking is recorded, it is sufficient to take a sample covering 3 to 5 days of each month for the butterfat determination.

Those who feel that they cannot spend the time necessary to weigh each milking may obtain reasonably satisfactory records by weighing and sampling the milk of each cow regularly on 3 consecutive days each month thruout the year. The average yield of milk and fat for this period is taken as the average for the month. Another method of less value, but better than no testing, is to record the production of each cow for 7 consecutive days at intervals of 3 months.

Tests covering only a week or even a month of the year are far less reliable than yearly tests, for cows differ widely in persistence of milk yield. A cow which gives a good flow of milk for a time but goes dry relatively soon may be much less profitable than a persistent milker that never yields as much fat in any one week as does the first cow.

For example, Glover[9] reports that during 3 years the best weekly record of one cow in an Illinois dairyman's herd was 309 lbs. of milk and 10.5 lbs. of fat. In her best lactation period, which lasted 266 days, she produced 5,355 lbs. of milk and 184 lbs. of fat. The best weekly record of another cow was 197 lbs. of milk and 10.2 lbs. of fat, less than the first cow. During her best lactation period (315 days) this cow,

[9]Ill. Cir. 84.

however, yielded 7,190 lbs. of milk and 367 lbs. of fat. This well shows the unreliability of short tests. Time, the scales, the Babcock fat test, combined with good judgment, are all essential in determining the true value of dairy cows.

547. Dairy cow censuses.—The importance of several factors in determining whether or not a fair profit will be made in dairying is well shown in the dairy cow censuses, conducted several years ago by *Hoard's Dairyman*. Following the first "cow census," conducted under the supervision of W. D. Hoard in 1887, a series of 26 canvasses were taken from 1899 to 1908, including 2,163 herds which contained 28,447 cows. In the following table are summarized some of the most important data compiled in these extensive surveys:[10]

Summary of the Hoard's Dairyman cow censuses

	No. of cows	Annual yield of butter fat	Cost of feed	Gross returns	Returns over cost of feed	Received for $1 worth of feed	Feed cost of butter fat per lb.
		Lbs.	Dols.	Dols.	Dols.	Dols.	Cts.
Type of cow							
Good dairy type	9,365	189.0	33.95	51.33	17.38	1.51	18.5
Lacking dairy type	8,104	138.2	32.01	34.04	2.03	1.06	23.0
Value of silage							
Herds fed silage	6,689	181.8	34.98	48.48	13.50	1.39	18.9
Not known to be silage-fed	21,759	151.2	32.95	39.41	6.46	1.20	22.2
Value of good stables							
Herds in good stables	9,506	180.0	34.53	48.65	14.12	1.41	18.7
Herds in poor stables	3,775	130.0	32.53	32.76	0.23	1.01	26.6
Value of dairy literature							
Owners read dairy papers	6,202	185.0	34.78	49.32	14.54	1.42	17.5
Owners read no dairy papers	9,122	136.7	35.00	36.85	1.85	1.05	28.8
Good and poor producers							
Most profitable herds	3,848	234.0	33.66	59.84	26.18	1.78	14.5
Least profitable herds	3,459	102.2	33.76	40.46	−6.70	0.80	32.1

The various differences recorded are not wholly due to the different single factors. For example, the low results from the herds in poor stables were not due to this alone but also to the fact that, compared with the cows in good stables, a greater proportion of these cows were undoubtedly lacking in dairy type and that a smaller number were fed silage or belonged to progressive owners who read dairy literature and applied its teachings in their business. The poor dairyman is usually deficient in not one but in many particulars. While the herds in which the cows were of good dairy type returned $17.38 per cow on the average over cost of feed, the herds lacking in dairy type little more than paid for the feed they ate. The cows fed silage yielded $1.39 for each dollar's worth of feed consumed, while those not known to have been fed silage

[10]Compiled in U. S. Dept. Agr., Bur. of Anim. Indus., Bul. 164.

returned but $1.20. Dairymen who read dairy papers secured a profit over cost of feed of $14.54 per cow, while those not directly influenced by dairy literature received only $1.85 per cow.

Such data as these show clearly the necessity of carrying on dairying in an efficient and business-like manner, if a good return is to be made.

548. Cow-testing associations.—The remarkable development of dairying in the Scandinavian countries of northern Europe has been largely due to the work of cow-testing associations. Cow-testing associations are now increasing rapidly in the United States and have already accomplished much good. In these organizations a trained tester is employed, who spends a day every month with each of the herds in the association. Arriving on the farm in the afternoon he weighs and samples the milk from each cow at milking time. He furthermore weighs the concentrates given each cow and also the roughage which several get and then estimates the approximate amount given to each cow in the herd. The following morning this is repeated, after which the samples of milk are tested for butter fat. From this day's record he computes the milk and fat production and cost of feed for each cow for the current month. While such records are not as exact as if every milking were weighed, careful studies have shown the results to be within 2 per ct. of the actual production of the cow. The tester also studies the local feed market and aids the dairyman in working out economical rations. Many dairymen who would not test their herds themselves are glad to secure this service at small expense as a member of the association. The improvement wrought by these associations is marvelous. In Denmark, largely due to their work, the average annual yield of butter per cow increased from 112 lbs. in 1884 to 224 lbs. in 1908. The first association in the United States was organized in Michigan in 1905 by Rabild, later of the United States Department of Agriculture. During the first 8 years the average yield of butter fat per cow in 7 herds which had been in the association from the beginning, was increased from 231.1 to 284.7 lbs., and the average net returns over cost of feed were more than doubled.

549. Official tests and advanced registry of dairy cows.—The establishment by the dairy breed associations of advanced registers for pure-bred cows is another important development of the dairy industry. Cows are entitled to advanced registry only when their yield in tests conducted by representatives of the state experiment stations or of the breed associations has reached a standard set by the association. Entry in these registers increases the money value, not only of the given cow, but also of her relatives, for progressive breeders in buying animals now rely more and more on records of production instead of merely show-ring successes.

550. Records of great cows.—Thru skilled breeding combined with expert feeding, truly marvelous records of dairy production have been secured. The world's records have been steadily raised during recent years until now Bella Pontiac, a 5-yr.-old pure-bred Holstein, has pro-

duced 1,270.0 lbs. butter fat in a single year, and Segis Pietertje Prospect, another Holstein, holds the record for milk production, with 37,381.4 lbs. milk to her credit in one year when 6 years old. Other records of champion cows are given in Chapter XXIV, with statements concerning the rations which were fed them in making their phenomenal productions.

II. Factors Influencing the Composition and Yield of Milk

551. Composition of milk.—The milk of different breeds of cows and even of individual cows of the same breed varies quite widely in composition. While the fat content may range from less than 3 per ct. to 7 per ct. or over, there is much less range in the other constituents. The milk sugar commonly ranges from 4 to 5 per ct., the casein from 2 to 3 per ct., the albumin from 0.4 to 0.9 per ct., and the mineral matter from 0.6 to 0.9 per ct.

The average composition of milk from the different breeds is shown in the following table:[11]

Composition of milk of different breeds

Breed	Total solids Per ct.	Fats Per ct.
Jersey	14.70	5.35
Guernsey	14.49	4.98
Devon	14.50	4.60
Shorthorn	13.38	4.05
Brown Swiss	13.27	4.24
Ayrshire	12.61	3.66
Holstein-Friesian	12.00	3.45

The Jerseys and Guernseys give the richest, and the Ayrshires and Holstein-Friesians the poorest milk. However the breeds which give the richest milk usually yield a smaller quantity, so that the amounts of fat and total solids produced are nearly the same for all of the recognized dairy breeds.

Eckles and Shaw[12] have shown that the sugar and albumin content of milk varies but little with either breed or individual, while there is a greater range in the percentage of casein. Milks rich in fat are generally high in casein, but the casein content does not increase in the same ratio as the fat content. According to Hart and Tottingham[13] for each 100 lbs. of fat in Jersey or Guernsey milk there are as a rule 55 to 65 lbs. of casein, while in Ayrshire and Holstein milk there are 65 to 75 lbs. The ratio of fat to casein shows considerable variation among cows of the same breed. These facts are important in cheese making since the yield of cheese depends not only upon the amount of fat in the milk but also upon its casein content. A milk testing 6 per ct. of fat will not

[11] Chiefly from Wing, Milk and its Products, p. 33.

[12] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 156.

[13] Agricultural Chemistry, p. 291.

make twice as much cheese as one testing 3 per ct. Therefore, at cheese factories where the milk from different herds differs considerably in fat content, it should be paid for, not on the basis of the fat content alone, but by some method which gives credit for both fat and casein.

Not only does the composition of milk depend on the breed but it is also influenced by the factors discussed in the following paragraphs.

It is well known that the fat in milk is in the form of minute globules or droplets, which are distributed thruout the milk in the form of an emulsion. The fat globules of Jersey and Guernsey milk are considerably larger than those in Holstein and Ayrshire milk, while the size of the globules in Shorthorn milk ranges between. The fat will rise to the surface most rapidly in milk containing large fat globules.

So minute in size are the fat globules that the number secreted by a cow in a day is beyond comprehension. It has been estimated that an average cow in full flow of milk secretes at least 138,210,000 fat globules each second thruout the day of 24 hours. Babcock [14] has computed that a quart of average milk contains not less than 2,000,000,000,000 fat globules. These figures will illustrate the marvelous processes which are constantly going on in life.

552. Influence of individuality.—Cows of the same breed differ one from another, both in the amount of milk they produce and in its composition, especially the percentage of fat. Indeed, cows of the same breed may yield milk differing as much in fat percentage as the average differences between the several breeds. The milk from an individual cow may also vary considerably in fat percentage from day to day, due to changes in health, change of milkers, excitement, variations in weather, and, in small degree, to changes in feed.[15]

The cow that gives the richest milk does not necessarily produce the largest total yield of fat. Eckles states that as a rule the highest annual productions of butter fat are generally secured with milk carrying the average percentage of fat for the breed or even less.[16]

To determine the variation in the percentage of fat in single milkings of individual cows, Anderson[17] studied 200 seven-day records made under ordinary herd conditions where regular feeding and milking were practiced, and 2,000 seven-day records of official Advanced Registry tests. From these data he draws the following conclusions:

One may expect that during 7 consecutive days about 30 per ct. of a herd of cows will show a range in the percentage of fat in the milk at different milkings of 1 per ct. or less; 50 per ct. of 1.1 to 2.0 per ct.; 14 per ct. of 2.1 to 3.0 per ct.; and the remaining 6 per ct. of the herd even a greater variation. In other words, 6 per ct. of the cows might yield milk testing 3 per ct. of fat at one milking during the week and at some

[14] Wis. Bul. 18.

[15] Eckles and Shaw, U. S. D. A., Bur. Anim. Indus., Bul. 157.

[16] Dairy Cattle and Milk Production, pp. 133-4.

[17] Mich. Spec. Bul. 71.

other milking produce milk containing 6 per ct. of fat or over. The fluctation in the composition of the milk from the same cow is thus much greater than has often been assumed.

White and Judkins of the Connecticut (Storrs) Station[18] point out that due to the variations in percentages of both fat and solids-not-fat in the milk of different cows, it is essential when the milk is to be sold on a city market to strain the milk from all the cows into a large can or tank where it can be thoroly mixed before bottling or putting in small cans. Otherwise the milk in some of the containers may fall below the legal standards for fat or solids-not-fat.

553. First and last drawn milk.—The first milk drawn from the udder is very poor in fat, each succeeding portion increasing in richness. In a trial by Van Slyke at the New York (Geneva) Station[19] the first portion of milk drawn from a Guernsey cow contained but 0.76 per ct. fat; the second, 2.60 per ct.; the third, 5.35 per ct.; and the last, 9.80 per ct. The percentages of casein and albumin vary but little, decreasing slightly as the milk becomes richer in fat.

554. Effect of period between milkings.—When the intervals of time between milkings are unequal, cows generally yield a smaller amount of milk after the shorter period, but this milk is slightly richer in fat and total solids. For this reason the evening milk is usually richer than that drawn in the morning. Where the intervals are equal there is no regular difference in quality with cows milked twice a day. When they are milked 3 times daily the mid-day milking is usually the richest.[20]

555. Effect of age.—The annual yield of both milk and fat by a cow normally increases from the first lactation until she is mature. The maximum yield is usually reached at from 7 to 9 years of age. On account of this, the requirements of milk or fat production by the various breed associations for entry of cows into the advanced registry increases with the age of the cow until maturity is reached.

From a study of all the data bearing on the effect of age of the cow on the yield and fat content of milk Eckles[21] concludes:

"A dairy cow on the average as a 2-yr.-old may be expected to produce about 70 per ct.; as a 3-yr.-old around 80 per ct.; and as a 4-yr.-old about 90 per ct. of the milk and butter fat she will produce under the same treatment when mature.

"Probably the majority of dairy cattle are rejected from the herd on account of failure to breed, or from udder trouble before the effect of advancing years can be observed to any marked extent. It is a fact often observed that a cow may make her best record when 10 or 11 years old, altho as a rule she does her best rather earlier. If a dairy cow

[18]Conn. (Storrs) Bul. 94.

[19]Jour. Am. Chem. Soc., 30, p. 1173.

[20]Eckles and Shaw, U. S. D. A., Bur. Anim. Indus., Bul. 157.

[21]Dairy Cattle and Milk Production, p. 153.

continues to breed, she usually shows no marked decline until at least 12 years old. Occasionally a cow continues to breed until she is 16 or 18 years old.'' Eckles and Palmer[22] report that the milk from a cow that was 19 years old and in her thirteenth lactation period was pronounced to be of excellent quality.

The age of the cow has but little effect upon the percentage of fat in her milk.[23] From studies of the advanced registry records of cows of the Ayrshire, Jersey, Guernsey, and Holstein breeds, including a total of 19,002 yearly records, White and Judkins of the Connecticut (Storrs) Station[24] conclude that on the average the fat test is highest for the first lactation and gradually and very slowly declines until maturity is reached, but nearly half of the cows whose records were studied proved exceptions to this general rule. Often the richness of the milk is lower in the first or second lactation period than in the following ones. After maturity, other factors are more important than age in determining the percentage of fat, and an animal may test even higher when old than when immature.

556. Effect of advancing lactation.—For a few weeks after freshening cows usually give somewhat richer milk than during the following month or two. The fat percentage then usually remains fairly constant until toward the close of the lactation period, when it gradually increases. The most marked effect of advancing lactation is upon the yield of milk. In well-managed herds the normal monthly shrinkage in milk flow is about as follows: From the second to the seventh month the shrinkage varies irregularly, ranging from 4 to 9 per ct. per month, based on the yield of the given cow for the previous month. The average monthly decrease during this period is about 6 to 7 per ct. After this the decrease becomes more rapid, being 9 to 11 per ct. for the eighth month, 12 to 18 per ct. for the ninth month, and 12 to 23 per ct. for the tenth month, after which the cows are generally dried off.[25]

The further advanced a cow is in lactation the more food she usually requires for a given quantity of milk, especially towards the end of the lactation period, when her production is low. For the first few weeks after calving a good dairy cow usually draws on her own body substance for some of the nutrients she uses in milk production, therefore apparently producing milk with surprising efficiency. On the other hand, late in the lactation period, when her production is low, most of her feed goes to maintain her body and to nurture the unborn calf.

[22]Jour. Agr. Res. 11, 1917, pp. 645-57.

[23]Gowen, Me. Buls. 279, 284, 290, 293.

[24]Bul. 94.

[25]Carlyle and Woll, Wis. Bul. 102; Woll, Wis. Bul. 116; Wis. Res. Bul. 26; Beach, Conn. (Storrs) Bul. 29; Linfield, Utah Bul. 68.

Pearl has published (Maine Station, Report of Progress on Animal Husbandry Investigations in 1915, pp. 3-8.) a table giving the theoretical percentage yield of cows of various ages and during the different months of the lactation period, taking as 100 per ct. the maximum monthly yield when mature.

557. Influence of condition at calving.—Observing dairymen have for some time known that when a good dairy cow calves in a fat condition she will often yield milk containing 1 to 2 per ct. more fat than normal, losing markedly in weight meanwhile, a fact which was brought to public attention by Woll[26] and Eckles[27]. This is due to her strong dairy temperament, which impels her to withdraw fat from her body and put it into her milk. The yearly yield of fat may thus be increased by having cows calve in good condition. Also, when a cow calves in high condition, a seven-day record of fat production secured shortly after calving may not be a reliable index to her ability as a long-time producer. Yearly records are therefore far more reliable guides to the value of dairy cows.

The following instance given by Eckles will illustrate this effect of the condition of the cow at time of calving. A mature cow was so fed as to be excessively fat at calving, and thereafter was given only sufficient food for a dry cow. Beginning with 21 lbs. of milk daily, she was giving 19.5 lbs. at the end of 30 days of such poor feeding, during which time she lost 115 lbs. in weight. Eckles estimates that the 43 lbs. of fat and 53 lbs. of other solids yielded in the milk during this period must have been drawn from her body tissues. During this period her milk averaged 6.1 per ct. fat. Within 48 hours after her feed was later increased the fat content fell about 1.4 per ct.

In another trial Eckles fed one heifer liberally on rich rations from birth until she calved, while another was kept poor and thin. After calving, the milk of the well-fed heifer tested over 4 per ct. fat and that of the thin one about 3 per ct. For several weeks after calving the fat heifer declined in weight, the fat percentage remaining constant. When at length her weight became stationary the percentage of fat declined somewhat. The thin heifer did not lose in weight after calving, and the fat in her milk did not decrease. In the end the milk of the two heifers was about equally rich.

Haecker[28] found that for the first few weeks of lactation cows of pronounced dairy temperament usually yielded milk greatly in excess of the nutrients in the feed they consumed, in some instances twice as much. This continued until about the eleventh week, when an equilibrium was usually reached between the nutrients consumed and the product yielded, but some cows required a longer time to reach a balance.

558. Influence of feed on yield of product.—It is pointed out later in this chapter that the kind and amount of feed do not materially change the richness of the milk. On the other hand, the amount of milk a cow will produce, and hence the total yield of fat, depends on the feed and care she receives, up to the point where her full capacity for milk production is reached. The typical beef cow usually has a very limited

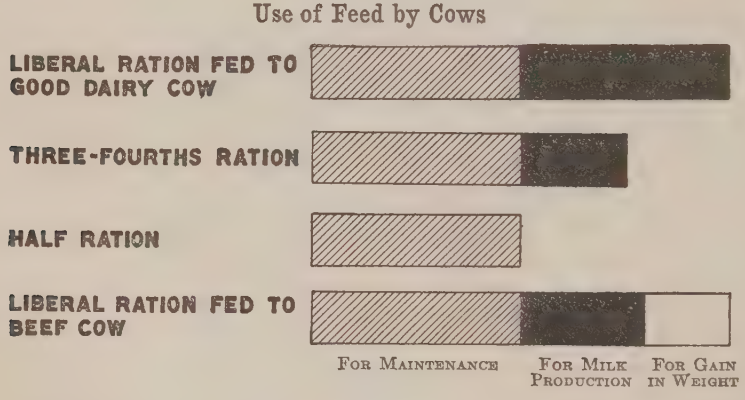
[26]Wis. Rpts. 1902, p. 117; 1903, p. 115.

[27]Hoard's Dairyman, 40, 1909, p. 696; Mo. Bul. 100.

[28]Minn. Bul. 79.

capacity for producing milk and yields only sufficient for her calf, even tho her feed be abundant. Any surplus of nutrients is stored in her body as fat. On the other hand, in the well-bred dairy cow the impulse to produce milk is so strong that with abundant and suitable feed and good care she yields much more milk than her calf requires.

Many dairymen make the serious mistake of failing to supply good dairy cows with enough feed for the most economical production. The following figure shows that a good dairy cow fed a liberal ration requires about half her feed to maintain her body and uses the other half to make milk. If she receives less feed, the proportion which she can use to produce milk will be decreased. For example, if fed three-fourths of a full ration, she can use only one-third of what she eats to make milk. Should she be fed but half of a full ration, she will still need as much as before to maintain her body and no feed will remain for milk production. Any milk she then yields would be made by robbing her body of nutrients. The true dairy cow thus produces milk most economically when fed a liberal ration, while a cow of beef type or one lacking in dairy temperament, when liberally fed, will store a considerable part of the food nutrients in her body as fat, instead of turning them into milk. A safe rule is to feed such a cow only what she will eat without gaining in weight.



It Pays to Feed Good Dairy Cows Liberally

When fed liberally a good dairy cow can use half her feed for milk production. When fed a three-fourths ration she can use only one-third of her feed for producing milk, and when fed a half-ration she needs all her feed to maintain her body. A beef cow, if fed a liberal ration, will turn part of her surplus feed into fat instead of milk. (After Van Norman.)

The increase in production due to good feed and care is shown in a striking manner in a trial by Wing and Foord at the New York (Cornell) Station[29]. A herd of cows poorly fed and cared for by their owner, was taken from a farm to the Station where they were liberally fed for 2

[29]N. Y. (Cornell) Bul. 222.

years. Then the cows were returned to their owner and fed by him as before. During the time the cows were at the Station they gave 42 per ct. more milk and 51 per ct. more fat than when with the farmer, due to the better feed and care they received.

559. Influence of feed on richness of milk.—Until recent years it was believed that milk varied in percentage of fat from milking to milking, according to the daily feed and care the cow received. We now know that if the cow receives sufficient nutrients to maintain her body weight, the percentage of fat can not be materially altered for any long period of time by greater or less liberality of feeding or by supplying any particular kind of feed. Cows starved or greatly underfed may produce milk somewhat lower in fat percentage than normal. Some feeds, as cocoanut meal, for example, apparently often cause a slight increase in the fat percentage of the milk, which may be more or less temporary.

Statements have often been made that certain feeds stimulate the production of milk and of fat to an extent not explained by the amounts of nutrients they supply. However, the results of the trials which have been carried on to study this matter disagree. A certain feed has been said in some instances to stimulate milk or fat production, and in other cases the same feed has had an unfavorable effect. In most such trials the experimental periods have been too short to warrant definite conclusions. Up to the present there is no very positive evidence of any continued specific effect of a feed in stimulating milk production or increasing the percentage of fat.

The Jersey cow gives milk which is relatively rich in fat, and the Holstein, milk that is relatively low in fat. No kind of feed or care will cause the Jersey to give milk like that of the Holstein, or the reverse. Were a piece of skin, clothed with yellow hair, taken from the body of a Jersey cow and grafted on the body of a Holstein cow, we should expect the grafted portion to continue growing yellow, Jersey-like hair. In the same way, were it possible to graft the udder of a Jersey cow on to the body of a Holstein, we would then expect the Holstein to give Jersey-like milk. It is not the body of the cow or the digestive tract, but the glands of the udder which determine the characteristics of the milk yielded by each individual cow. This is what we should expect, for if milk varied with every slight change of food and condition, the life of the young, dependent on such milk, would always be in jeopardy.

560. Can the yield of milk or fat be increased by feeding fat?—Numerous experiments have been conducted in this country and in Europe to determine the effect on the yield and fat content of the milk when various fats are added to the ration. After feeding cottonseed-, palm-, corn-, cocoanut-, and oleo-oil, and stearin, the solid fat from beef, to cows, Woods at the New Hampshire Station[30] concluded that the first effect of such feeding is to increase the percentage of fat in the milk, but with the continuance of such feeding the milk

[30]N. H. Bul. 20.

tends to return to its normal composition. Lindsey of the Massachusetts Station [31] likewise found that feeding large quantities of oil, either linseed, cottonseed, corn, or soybean oil, caused a temporary increase in the richness of the milk. That the feeding of fat does not always cause a temporary increase in the richness of the milk is shown in 2 trials by Wing at the New York (Cornell) Station[32] in which tallow was fed to 10 cows while on pasture or on winter feed. Beginning with a small amount, the allowance of tallow was gradually increased until each cow was consuming about 2 lbs. daily, this allowance being continued for several weeks. The tallow feeding had no uniform effect either on the yield of milk or the fat content.

561. Effects of feed on fat composition.—The fat of milk is a composite of many kinds of fat—palmitin, olein, stearin, butyrin, etc. While the kind of feed given the cow does not materially change the percentage of total fat in her milk, in some cases it does seem to alter the relative proportion of the several component fats or otherwise change the character or nature of the fat, as shown by the resultant butter. Many years ago investigators began to study diligently the influence of various feeds on the composition of the fat of milk, and their work is still in progress. The results thus far secured are conflicting in some respects, but in general it has been found[33] that feeds rich in vegetable oils (which contain a large amount of olein) produce milk fat high in olein. This usually tends to make the butter softer, for olein is a liquid fat, but in some instances this tendency is offset by still other changes in the composition of the fat. For instance, tho the feeding of cottonseed meal, cotton seed, or cottonseed oil increases the amount of olein in the butter fat, yet it raises the melting point and makes the butter harder. Eckles and Palmer[34] believe that this effect is due to the fact that these feeds decrease the amount of volatile fatty acids in the butter fat, which more than counterbalances the effect of the increase in the amount of olein. Cocoanut meal also produces a firm, hard butter. A change from dry feed to pasture generally produces fat higher in olein and results in softer butter.

562. Influence of underfeeding and overfeeding.—In extensive experiments at the Missouri Station[35] Eckles and Palmer studied the effects of underfeeding dairy cows in milk; i.e., supplying them with insufficient feed to furnish the nutrients required for milk production and maintain their weight, and also studied the effects of overfeeding.

When cows are underfed immediately after calving they will maintain their milk flow at a nearly constant level for a time under the most adverse conditions, drawing on their bodies for nutrients and losing in weight rapidly. In one case a cow kept up a normal flow of milk for a month when given only as much feed as would have been required to

[31] Mass. Rpt. 1908, pp. 109-112.
[32] N. Y. (Cornell) Bul. 92.
[33] Lindsey, Mass. Rpt. 1908, pp. 109-112; Hunzicker, Ind. Bul. 159.
[34] Mo. Res. Bul. 27.
[35] Mo. Res. Buls. 24, 25.

maintain her weight when dry. When the lactation period has reached a certain stage, even moderate underfeeding causes a decline in milk flow. Underfeeding following a period of liberal feeding causes a marked increase in the percentage of fat in the milk, especially when the cow has a surplus store of fat in her body. Underfeeding produces marked effects on the chemical and physical properties of the butter fat, which may or may not change the melting point. Ragsdale and Swett of the Missouri Station[36] report that when the ration of cows during the first half of the lactation period was reduced one-half, the percentage of fat was temporarily increased, the high point occurring either the second or third day after the reduction was made. As soon as the cows were put back on full feed the fat content of the milk fell and went even below normal. The amount of milk varied almost directly with the amount of feed given.

Eckles and Palmer found that the most pronounced effect of overfeeding; i.e., feeding a more liberal ration than is required for the production of a normal yield of milk, was that it caused the cow to gain in weight. Only to a limited extent was the excess food used for the production of milk and even under the most favorable conditions the animals seemed unable to increase their milk flow beyond the fixed maximum inherited by the individual. Overfeeding will sometimes cause a recovery of the milk flow lost because of previous poor nutrition, but this recovery is only partial even under the best conditions.

563. Effect of temperature, weather, and turning to pasture.—The tendency is for cows of all breeds to give richer milk when the temperature falls and poorer milk as it rises, and so they generally yield slightly poorer milk in summer than in winter. This was shown in 5 trials by Hills at the Vermont Station,[37] covering practically the entire year, and including varying conditions of pasture, summer soiling, and winter barn feeding. The same conclusion was reached by Eckles,[38] on studying the records for 240 lactation periods of cows in the herds at the Missouri and Iowa Stations, by White and Judkins,[39] on compiling the records for the herd at the Connecticut (Storrs) Station, and by Ragsdale and Turner of the Missouri Station[40] on studying the records of over 3,000 Guernsey cows which had made the Advanced Registry, and also records of Jerseys and Holsteins at the Missouri Station. No matter when a cow freshens, the tendency is for her to give richer milk in the winter months and poorer milk in summer, especially during June and July. White and Judkins found that the milk contained on the average 0.31 per ct. less fat and 0.56 per ct. less solids-not-fat in the summer than in the cold months. In any particular cow this tendency may be offset by the usual rise in percentage of fat during the last 2 or 3 months of lactation.

[36]Mo. Bul. 179, pp. 22-23.
[37]Vt. Rpt. 1907.
[38]Milchwirtschaftliches Zentralblatt, 5, 1909, pp. 488-502.
[39]Conn. (Storrs) Bul. 94.
[40]Information to the authors.

Cows exposed to cold rains or other severe weather shrink in milk flow and may yield milk low in fat.

When cows are turned from winter stables to spring pastures, usually both the yield of milk and its richness are slightly increased, but after 2 to 4 weeks the percentage of fat falls to normal. Especially when the grass is soft and lush, cows lose in weight for a short time when first turned to pasture.[41] The temporary increase in percentage of fat may be due to the fact that such early spring pasture is so watery that the cows cannot secure from it sufficient nutrients to meet the needs for their production and hence are forced to draw on their bodies. Such underfeeding, as has been pointed out, usually increases the fat content of the milk, if the cows are in a good state of nutrition.

564. Exercise and grooming.—Moderate exercise tends to increase the yield of milk and the richness of all constituents except casein, while too much exercise or hard work, such as milk cows are often used for in Europe, decreases the yield and injures the quality of the milk.

In trials in Germany[42] grooming increased the flow of milk 4 to 8 per ct. while in tests by Hills at the Vermont Station,[43] where the ungroomed cows were not allowed to become filthy, it brought no increase. Tho grooming may not increase the yield of milk, it does improve its quality by lessening the amount of sediment and the number of bacteria in the milk and may improve the health of the animals.

565. Milking machines.—Because of the difficulty of securing efficient hand milkers, the use of milking machines attracts wide-spread interest. The various types of machines have now been improved and long-continued trials at various stations[44] show that when cows are milked with the best machines by careful operators and with well-adjusted teat cups there is no injurious effect on the yield or quality of the milk, or on the health of the animals. While with most cows the machine does not draw quite all the milk from the udder and it is necessary to strip by hand, nevertheless a considerable saving in time results from the use of machines. Hooper and Nutter of the Kentucky Station[45] found at the Elmendorf dairy that 2 men required 3 hours to milk 50 cows by hand, aided by a boy to carry the milk to the house. Using 2 units per man, the men, aided by the boy as before, milked these cows in 1 hour and 15 minutes. Later, using 3 units per man, the 2 men alone milked the cows in 1 hour and 45 minutes. When the machines are properly

[41]Humphrey and Woll, Wis. Bul. 217; Hills, Vt. Rpt. 1907; Linfield, Utah Bul. 68; Copenhagen Station Rpt. 45.

[42]Jour. Landw., 41, 1893, p. 332.

[43]Vt. Rpts. 1899, 1900.

[44]Mairs, Penn. Bul. 85; Price, Tenn. Bul. 80; Haecker and Little, Nebr. Bul. 108; Woll and Humphrey, Wis. Res. Bul. 3, also Bul. 173; McMillan, Agr. Gaz., N. S. Wales, 22, 1911, pp. 859-868; Smith and Harding, N. Y. (Cornell) Bul. 353; Larsen, White, and Fuller, S. D. Bul. 144; Hooper and Nutter, Ky. Bul. 186; Larsen, S. D. Bul. 166.

[45]Ky. Bul. 186.

cleansed and the rubber tubing kept in an antiseptic solution, the sanitary condition of the milk is improved over that ordinarily obtained by hand milking. Owing to the first cost of the machines and the labor involved in their operation and cleansing, various authorities consider machine milking economical under usual conditions only where at least 15 to 30 cows are milked thruout the year.

566. Minor points.—Dehorning cows causes a small temporary decrease in milk flow but is repaid a hundred fold in the greater comfort of the herd thereafter. Subjecting cows to the tuberculin test has practically no effect on the yield of milk or fat. Milking three or four times a day may cause a slightly larger flow of milk, but it is not profitable except with very heavy milkers and cows on official test.

Contrary to considerable popular opinion, the period of oestrum, or heat, does not generally have any very marked effect on the yield of milk or butterfat. Hooper and Bacon found at the Kentucky Station[45a] that on the average cows gave 0.1 lb. less fat and 1.5 lbs. less milk on the day of most evident heat. Several cows were not thus influenced, but on the other hand, a few nervous cows were greatly affected.

From a study of 1,497 Register of Merit tests on Jersey cows, they report that cows not carrying calves tend to produce slightly more milk in a year than those which are pregnant.

Woodward, Turner, and Curtice of the United States Department of Agriculture[46] found that when cows which were immune to tick fever were infested with ticks the milk yield was reduced 34.2 per ct. on account of the depletion of the blood. In tick infested districts they advise spraying or dipping with an arsenical solution, at least when animals are heavily infested.

567. Flavor, odor, and color.—The flavor and odor of milk and its products are highly important. Due to minute quantities of volatile oils they contain, which are the source of the trouble, onions, leeks, turnips, rape, etc., give an objectionable flavor to milk, unless fed immediately after milking so that the volatile oils may escape from the body before the next milking. When cows are first turned to pasture, we at once note a grass flavor in the milk and butter, which soon disappears or which we fail to notice later.

Wild onions and leeks are often troublesome pests in pastures in early spring, causing off-flavor milk. Hooper of the Kentucky Station[47] reports that to avoid this cows may be grazed on pasture infested with wild onions for only 2 or 3 hours after milking and kept in a clean pasture or paddock 5 or 6 hours before the next milking. Quick cooling of the milk to 41°F. tends to drive off some of the volatile flavor.

Sometimes when a cow is far along in lactation her milk becomes bitter and distasteful. Eckles[48] states that so far as he has observed, this occurs only when the animal is far advanced in pregnancy and

[45a]Ky. Bul. 234.
[46]U. S. Dept. Agr. Bul. 147.
[47]Information to the authors.
[48]Dairy Cattle and Milk Production, p. 227.

rarely happens when green feed is supplied. He writes that reducing the grain ration and giving 2 or 3 doses of Epsom salts may remove the trouble.

The whole subject of odors and flavors in milk and dairy products is greatly complicated by the fact that there is a wide range in the ability of different individuals to detect and distinguish them. Flavors and odors plainly evident to one person are unnoticed by another. Often odors and flavors charged to feed or cow are due to contamination of the milk in the stable or elsewhere, after it is drawn from the cow. The flavors and aroma of butter are mostly due to fermentation of milk sugars, so that this matter rests only in part on feeding.

568. The yellow color of cream and butter.—It is common knowledge that cows produce cream and butter which is more deeply colored in summer when eating green feeds than in winter, and that Jerseys and Guernseys usually produce a yellower product than the other breeds. Extensive investigations by Palmer and Eckles at the Missouri Station[49] have at length shown that the color is due to a substance called carotin, so named because it is the coloring matter of the carrot. This compound is commonly found in green plants along with the green chlorophyll, which masks its color. (8) It was found that animals given feeds poor in carotin for long periods invariably produced white cream and butter fat, regardless of the breed. This shows that the yellow color of Jersey and Guernsey butter is not due to any ability of these breeds to manufacture carotin. However, when cows of these breeds are given feeds rich in carotin they transfer to their milk a larger part of the yellow coloring matter of the feed than do cows of the other breeds, and hence produce yellower butter fat. Green feeds in general were found to be rich in carotin, as well as hay of a bright green color and new corn silage. Carrots and other yellow roots also contain much of this coloring matter. On the other hand, bleached hay, dry corn fodder or stover, straw, old corn silage in which the carotin had been destroyed by fermentation, corn, both yellow and white, and all the common concentrated by-products, such as wheat bran, linseed meal, brewers' grains, etc., were found to be poor in carotin. This explains why cows usually produce light-colored butter in winter. The color of yellow corn is due to a colored substance other than carotin, which does not pass into the milk.

The yellow color of the body fat and skin of Jerseys and Guernseys was found to be due to carotin. This shows why cows of these breeds yield a highly colored product for a long time after going on winter feed. During such periods the yellow coloring matter in their body fat is transferred to the milk. Purchasers often discriminate against beef having deeply colored fat, yet this tallow is colored by the same substance that gives butter the highly desired yellow color.

[49] Mo. Res. Buls. 9, 10, 11, 12; also Cir. 74.

III. Nutritive Requirements of Dairy Cows

569. Nutrients required by dairy cows.—The general feed requirements for milk production have been discussed in a previous chapter, and there compared with the requirements for growing animals and for those which are being fattened. (**147-50**) It is there pointed out that milk is rich in protein and in mineral matter, especially calcium and phosphorus, and that therefore the ration of the cow producing milk must contain an abundance of these nutrients. It has further been emphasized that the dairy cow in milk needs a ration high in net energy, due to the large amounts of milk sugar and of butter fat she yields in her milk. Therefore for continued high production she must receive a fairly liberal allowance of concentrates, in addition to roughage of good quality.

570. Vitamine requirements.—Dairy cows which are fed well-balanced rations, including plenty of good-quality legume hay, and are supplied with good pasturage or other green feed during the summer will secure an ample amount of the fat-soluble vitamine for health, for green-leaved plants are rich in this vitamine and it is not destroyed by drying. Furthermore, such rations will furnish plenty of the water-soluble vitamine, for as has been pointed out earlier, this is contained in ample amounts in practically all common stock feeds. (**104**) Also, there will be no deficiency of the anti-scorbutic vitamine. Cattle are not affected by scurvy, as are man, monkeys, and guinea pigs, either because they do not require this vitamine, or because it is contained in ample amount in all rations. Therefore, except for the possible relationship of a vitamine to the assimilation of calcium, which is discussed later, the rations ordinarily recommended for dairy cows apparently furnish an ample supply of vitamines.

571. Requirements for maintenance, growth, and pregnancy.—A dairy cow in full flow of milk needs nearly half the nutrients in the feed she consumes merely for maintaining her body. In addition to these needs for maintenance, if she is immature she will require additional nutrients for the growth of her body tissues. During the time she is pregnant, she will need nutrients for the building of the fetus. She can use in actual milk production only the amount of nutrients which is left after these needs have been met.

It has been pointed out in Chapter VII that in computing rations for a dairy cow by most of the modern feeding standards, first the maintenance requirements are computed on the basis of her weight, and then to these amounts of nutrients are added the requirements for the production of the milk she is yielding. In the Wolf-Lehmann, Haecker, Savage, Woll-Humphrey, and Morrison standards the daily maintenance requirements per 1,000 lbs. live weight are given as 0.70 lb. digestible crude protein and 7.925 lbs. total digestible nutrients. In the Armsby and Eckles standards the maintenance requirements of the 1,000-lb. cow are stated as 0.50 lb. digestible protein (not crude protein) and 6.00

therms of net energy. As these requirements are stated in different terms, they can be compared only indirectly. It will be found that when legume hay, or a combination of legume hay and such feeds as corn stover or straw, are taken for a maintenance ration, about the same amount of feed will be needed to meet the requirements for the net-energy standards as for the standards based on total digestible nutrients. On the other hand, if feeds higher in net energy, such as either good corn silage or else concentrates, are used as part of the maintenance ration, less feed will be needed to meet the net energy requirements expressed in therms than to satisfy the standards based on total digestible nutrients.

The most extensive investigations which have been conducted to determine the maintenance requirements of dairy cows are those of Hills and his colleagues at the Vermont Station.[50] In these trials, which have been carried on from 1907 to 1920, a total of 20 cows have been fed while dry and barren for periods of 391 to 2,701 days. Ten of these cows were fed less than the maintenance requirements as given in the standards based on digestible nutrients, some being fed 40 per ct. less. The cows, however, suffered in no wise, but, instead, gained in weight. These data seem to indicate that these standards prescribe more feed than is actually required for the mere body maintenance of a dry dairy cow when mature and not pregnant.

Data secured from 14 cows in these trials indicate that the building of the fetus when a cow is pregnant makes relatively little additional draft for non-nitrogenous nutrients, but may require on the average 0.05 to 0.10 lb. daily of digestible protein, spread over the entire gestation period, in addition to the amount needed for mere maintenance. This need for additional protein is naturally greatest during the last third of gestation, when the development of the fetus is most rapid.

The requirements for the development of the fetus have also been studied by Eckles at the Missouri Station.[51] He fed 2 cows during their entire gestation periods on rations which had previously been only sufficient to maintain their weight when not pregnant and not producing milk. The cows developed normal calves, and their average weight was greater after calving than before the trial started. Similar results were secured in another trial. Eckles believes these results are due to the relatively small amount of dry matter in the fetus, which has already been discussed (121), and also probably to the cows requiring less feed for mere body maintenance when pregnant, owing to their being quieter.

Hills believes from his investigation that a ration which furnishes sufficient nutrients to meet the requirements for maintenance and for the production of the amount of milk yielded, will suffice for the first two-thirds of the gestation period. For the last third of the period it should be sufficient to add to the nutrients required for maintenance and for

[50]Information to the authors.

[51]Mo. Res. Bul. 26.

producing the small amount of milk then yielded, twice the nutrients contained in the new-born calf.

General experience has shown, as stated in Chapter XXIII, that it pays to allow a cow to go dry 6 to 8 weeks before calving and to feed her during this time so that she will be in fairly good flesh when she calves. When this practice is followed and legume hay and some protein-rich concentrate are included in the ration, the requirements for the building of the fetus will be amply met.

572. Requirements for milk production.—Since Haecker's extensive investigations were carried on (182), it has been generally recognized that the additional requirements of cows in milk beyond the nutrients needed for mere body maintenance, depend not only on the amount of milk produced, but also on its fat content. The recommendations of the various feeding standards for milk production have been compared in Chapter VII (182-6,189), and it has there been pointed out that more concentrates are required to meet the recommendations of the Haecker, Savage, and Morrison standards than to meet the Armsby net energy standards.

In a trial by Morrison, Humphrey, and Putney at the Wisconsin Station,[52] which has been mentioned previously (186), good dairy cows produced 2.22 lbs. more milk and .07 lb. more butter fat on a ration balanced according to the Savage standards than on a ration containing 3 lbs. less concentrates, which met the requirements as stated in the Armsby standards. Furthermore, the cows gained slightly more in live weight on the Savage ration. From his extensive investigations at the Vermont Station, Hills likewise concludes that for maximum production as much total digestible nutrients are required as is advised in the Savage standards.

We may, therefore, conclude that unless concentrates are high in price compared with roughages, it will pay to feed dairy cows of good productive capacity enough concentrates to meet the recommendations of the Savage standards or to bring the total digestible nutrients to the higher of the two sets of figures given in the Morrison standards. When concentrates are high in price, it may be more economical to feed only enough concentrates to meet the Armsby standards, or enough to bring the total digestible nutrients in the ration to the lower of the two figures given in the Morrison standards. The amount of concentrates to feed dairy cows is discussed later in Chapter XXIII. (646-7)

573. Protein requirements.—It has already been pointed out that dairy cows require rations much richer in protein than do fattening animals or work horses, due to the large amounts of protein contained in their milk. (148) Authorities differ somewhat as to the exact amounts of protein advisable. While Savage recommends that dairy cows be fed rations having nutritive ratios no wider than about 1 : 6, Haecker concluded from his trials that rations having a nutritive ratio of about 1 : 7 were as satisfactory as those furnishing more protein.

[52] Wis. Bul. 323, pp. 7-8.

It has previously been pointed out that protein is a cell stimulant and that a supply somewhat above the minimum promotes the well-being of the animal. Perhaps for these reasons, it is the general practice in feeding cows on official test to give much larger amounts of protein than is required to meet the recommendations of any of the feeding standards.

From trials at the Massachusetts Station[53] Lindsey concludes that feeding an excess of protein over the actual amount required for body maintenance and milk production tends to stimulate the cow to a greater yield of milk. In one test, supplying twice the minimum amount of protein required increased the milk flow 15 per ct. While the yield of milk may be thus increased by feeding an excess of protein, Lindsey concludes from 8 trials that varying amounts of protein do not seem to influence the percentage composition of the milk, making it richer or poorer in fat, for example. On the other hand, the experiments of the Copenhagen Station,[54] covering observations with about 2,000 Danish cows and extending over ten years, indicate that the fat percentage was possibly raised as much as 0.1 per ct. thru the feeding of highly nitrogenous rations. Michels of the North Carolina Station[55] found the fat content of the milk slightly higher when a ration having a nutritive ratio of 1:4.0 was fed than when the nutritive ratio was 1:5.7.

To produce the large amount of protein in her milk efficiently, the dairy cow must receive proteins furnishing a well-balanced supply of amino acids. Therefore, it was found in trials by Hart and Humphrey at the Wisconsin Station, which are mentioned in Chapter VI, that gluten feed (a corn grain by-product) was a much less efficient protein-rich supplement than linseed meal when added to a ration of corn grain and corn stover. (**148**) However, when fed with alfalfa hay, corn silage, and corn grain, there was little difference in the efficiency of gluten feed compared with linseed meal, cottonseed meal, and dried distiller's grains, due to the fact that the proteins in the alfalfa hay balanced the deficiencies of the proteins in the corn grain and gluten feed. In a trial at the South Dakota Station[55a] by Larsen and colleagues the protein of gluten feed was even superior in efficiency to that of linseed meal in supplementing prairie hay and corn silage.

From these trials we may conclude that in the common mixed rations usually recommended for dairy cows, in which silage and hay (preferably from the legumes) are combined with grains, there is little difference in the efficiency of the proteins furnished by the various protein-rich supplements. In other words, when fed in such rations, a pound of digestible crude protein in one supplement will have about the same value as a pound of digestible crude protein in the other available supplements.

Many experienced dairymen prefer concentrate mixtures made up of a reasonable variety of feeds to using only two concentrates in the ration.

[53]Mass. Rpt. 1911, I, pp. 86-121.
[54]Copenhagen Sta Rpt. 45; Woll, Wis. Bul. 116.
[55]N. C. Rpt. 1911, pp. 90-97.
[55a]S. D. Bul. 188.

The good results secured with such mixtures may possibly be due in large part to a better mixture of proteins furnished by such a variety of feeds. However, as is pointed out later, it is not necessary for good results to use a complicated concentrate mixture made up of a large number of feeds, if good roughages are fed, such as silage and legume hay. (**650**)

574. Mineral requirements.—The mineral requirements for milk production have been discussed in considerable detail in Chapter VI. (**149**) The investigations of Forbes, which are there summarized, show that the demand for calcium and phosphorus is so large with high-producing cows in full flow of milk that they may be unable to assimilate enough of these mineral constituents from their feed to prevent loss from their bodies, even when fed plenty of legume hay and protein-rich feeds, these making a ration quite high in both calcium and phosphorus.

Our knowledge concerning the cause of this surprising condition is as yet fragmentary. As has been pointed out earlier (**149**), possibly the milk-producing capacity of our dairy cows has been so increased by selective breeding that it exceeds the ability of high-yielding cows to assimilate sufficient mineral nutrients from their feed to meet the heavy demand brought about by the large milk flow during the first part of the lactation period. Forbes[56] has recently shown that later on in lactation, or when they are dry, they are able to build up again the stores of these mineral constituents in their bodies.

The losses of calcium which may occur when a cow is fed a ration deficient in this mineral nutrient are shown in a trial by Hart, McCollum, and Humphrey at the Wisconsin Station.[57] A cow producing about 30 lbs. of milk daily was fed a ration which was liberal, except that it lacked calcium. It was estimated that during the trial the cow gave up about one-fourth of the calcium in her skeleton, in order to keep the composition of her milk constant. This is an excellent example of the overpowering force of maternity.

In recent experiments at the Wisconsin Station[58] Hart, Steenbock, Humphrey, and colleagues have found that dairy cows and milk goats are able to assimilate calcium more completely from fresh green forage than from dried forage. They believe that this is due to the green forage containing larger amounts of the vitamine which is necessary for the assimilation of calcium from the food. (**104**) This view is substantiated by the fact that in certain instances where cows have been maintained for years without pasture or other fresh green feed, their production is lowered.[59] In these Wisconsin trials alfalfa hay cured under caps was apparently superior to that exposed to sunlight while being cured.

[56]Am. Soc. Anim. Production, Proceedings, 1921, pp. 70-79; Jour. Biol. Chem., 52, 1922, pp. 281-315.

[57]Wis. Res. Bul. 5.

[58]Wis. Bul. 323, p. 17; Res. Bul. 49, p. 18; Jour. Biol. Chem., 53, 1922, pp. 21-30; 54, 1922, pp. 75-89.

[59]Ohio Bul. 346, p. xxiv.

In experiments at the Beltsville, Maryland, Station of the United States Department of Agriculture[60] by Meigs and Woodward, the production of cows which had but little pasture or green feed during the year was increased in the following lactation period by adding sodium phosphate (a soluble phosphate) to the concentrate mixture fed during the dry period of 60 days before freshening. About 10 lbs. of sodium phosphate (Na_2HPO_4. $12H_2O$) was added to each 100 lbs. of the concentrate mixture, and the cows were fed a daily average of 3 to 6 lbs. of concentrates, with corn silage and alfalfa hay. The effect of the phosphate feeding was not noticeable in the case of cows that had been very liberally fed the preceding year because they had been on official test.

These various trials emphasize the importance of pasture and other green forage for dairy cows during the growing season, and of an abundance of well-cured legume hay during the rest of the year. Also, the cows should be dry from 6 to 8 weeks before freshening, and during this time should be so fed that they will be in good condition at calving. (**661**) When plenty of well-cured legume hay is not available, or when for any other reason there is possibility of the supply of calcium or phosphorus in the ration being low, mineral supplements should be added to the ration. Both calcium and phosphorus may be supplied by adding 3 to 4 lbs. of steamed bone meal or ground rock phosphate to each 100 lbs. of the concentrates, or only 2 lbs. if the ration is already fairly high in calcium and phosphorus. Calcium alone may be furnished by adding the same amounts of finely ground limestone, air-slaked lime, chalk, or wood ashes to the concentrates. That abortion or weak calves result when pregnant cows receive rations low in lime, such as straw with grain and grain by-products, has been pointed out in a previous chapter. (**98**)

If trouble is experienced from goitre or "big neck" in calves, this may be prevented by the administration of iodine to the cows thruout pregnancy, as is discussed in Chapter IV. (**101**) According to Kalkus[61] of the Washington Station, the iodine may be given by any one of the following methods: (1) Two grains of potassium iodide per head daily may be mixed with the feed. This may be done conveniently by sprinkling on the feed one tablespoonful of a solution of one ounce of potassium iodide to one gallon of water. (2) One teaspoonful of tincture of iodine may be poured on the pregnant animal's back once every two weeks. The iodine should not be poured on the same spot each time or it will blister the skin and cause the hair to fall out. (3) Ten cubic centimeters (about one-third ounce) of a 10 per ct. solution of iodine may be injected under the skin of the cow with a hypodermic syringe every two weeks during pregnancy. The same doses can be used for mares as for cows.

It has been pointed out previously and is also emphasized in a later chapter that dairy cows should always have plenty of salt. (**100, 653**)

[60]U. S. D. A. Bul. 945.

[61]Wash. Pop. Bul. 117; Bul. 156.

CHAPTER XXII

FEEDS FOR THE DAIRY COW

I. Carbonaceous Concentrates

The numerous studies of the cost of milk production which have been carried on by the experiment stations and other agencies during recent years have shown that on many farms, even where well-bred dairy cows are kept, milk has been produced at little or no profit to the owner. Yet, by a wise selection of feeds and intelligent feeding, other dairymen secure goodly profits from cows no better. This shows emphatically that the feeding of the herd must be given most careful study and the system of farming so planned that a ration both well-balanced in nutrients and otherwise satisfactory may be provided at minimum expense.

575. Indian corn.—Thruout the corn belt Indian corn, a grain highly relished by the cow, is usually the cheapest carbonaceous concentrate available for the dairy herd. Corn meal is very palatable to dairy cows and may well form a large part of their concentrate mixture, for it is rich in digestible carbohydrates and fat, needed in large amounts in milk production. However, in feeding corn its limitations should always be clearly realized; i.e., that it is low in protein and mineral matter, especially lime, and that it is a heavy rather than a bulky feed. For these reasons corn should always be fed with sufficient protein-rich feeds to balance the ration. Also, it is best to use it as only part of the concentrates, along with bulkier feeds like wheat bran or ground oats.

The poor results which follow when corn is fed in an unbalanced ration are shown in a trial by Fraser and Hayden at the Illinois Station[1] in which one lot of cows was fed for 131 days on corn as the only concentrate, with timothy hay, corn silage, and only a small amount of clover hay as roughage. Another lot was fed the well-balanced ration shown in the table.

Corn requires supplement for feeding dairy cows

Average ration		Nutritive ratio	Average daily yield Milk Lbs.	Fat Lbs.
Lot I, balanced ration				
Ground corn, 3.3 lbs. Gluten feed, 4.7 lbs.	Clover hay, 8 lbs. Corn silage, 30 lbs.	1 : 6	30.1	0.96
Lot II, unbalanced ration				
Ground corn, 8 lbs.	Timothy hay, 5 lbs. Clover hay, 3 lbs. Corn silage, 30 lbs.	1 : 11	20.5	0.69

[1]Ill. Bul. 159.

As soon as Lot II was changed from the excellent ration they had previously been fed to the unbalanced ration shown in the table, which had a nutritive ratio of 1:11, they fell off sharply in production. While the cows in Lot I were seldom off feed, this occurred frequently in Lot II. During the trial the cows in Lot I produced 47 per ct. more milk and 39 per ct. more fat than those in Lot II.

At the Maryland Station[2] Patterson fed cows on corn meal with dried corn fodder and soilage corn as the chief roughages during the entire lactation period. Others were given a well-balanced ration of gluten feed, wheat bran, and corn meal, with the same roughages. The next year the rations were reversed so that each cow was on both sides of the trial. On the unbalanced ration containing corn meal as the sole concentrate, the average annual yield of the cows was only 3,150 lbs. of milk or 152 lbs. of butter. When the protein-rich concentrate mixture was fed, the yield of milk was increased 33 per ct. and that of butter over 45 per ct. These trials show the folly of expecting profitable production from such unbalanced rations, even tho they may be palatable.

576. Feeding corn in various forms.—Corn is commonly ground for the dairy cow, but sometimes ear corn, shock corn, or corn-and-cob meal is fed. To determine whether it was most economical to feed corn meal, corn-and-cob meal, or ear corn, McCandlish fed 5 cows by the reversal method for 5 periods of 30 days each at the Iowa Station.[3] Equal amounts of dry corn grain were fed in the various forms with a basal ration of corn silage, clover hay, and a mixture of 4 parts of wheat bran, 4 of linseed meal, 2 of cottonseed meal, and 1 of ground oats. In this trial 100 lbs. of corn grain fed in the form of corn meal was worth 16 per ct. more than the same weight of grain (not including the cobs) fed in the form of ear corn. There was no advantage in feeding corn-and-cob meal in place of corn meal in this ration, which contained sufficient wheat bran to make the concentrate mixture quite bulky, without the addition of the ground corn cobs. In other words, 100 lbs. of corn grain in the form of corn-and-cob meal was worth no more than 100 lbs. of corn in the form of corn meal.

On the other hand, Cook of the New Jersey Station[4] found corn-and-cob meal slightly more economical than corn meal when fed with cottonseed meal, a heavy feed, as the only other concentrate. Lane of the same station[5] secured 9.3 per ct. more milk when feeding corn-and-cob meal as half the concentrates than when an equal weight, including cob, of broken ear corn was fed. These trials show that it usually pays to grind corn for dairy cows, rather than to feed ear corn or shelled corn. When other bulky concentrates are not included in the ration, it may be advisable to feed corn-and-cob meal. (**423, 656**)

577. Hominy feed.—This carbohydrate-rich by-product is quite similar to corn in composition and compares favorably with it in feeding value.

[2]Md. Bul. 84.
[3]Iowa Bul. 195.
[4]N. J. Rpt. 25, pp. 159-167.
[5]N. J. Rpt. 1898, pp. 211-215.

(213) Like corn, it must be supplemented by feeds rich in protein. Since hominy feed is kiln-dried, it keeps better in storage than corn meal.

578. Wheat.—Wheat, which is usually too high priced for feeding, except when damaged or otherwise low in quality, was found by Bartlett at the Maine Station[6] to have about the same value when ground as corn meal for dairy cows. In Denmark ground wheat was fully equal to mixed barley and oats.[7] Wheat should be ground or preferably rolled for cattle. Like corn it is a heavy feed, and it is best to mix it with some bulky concentrate. (215)

579. Oats.—This grain, which supplies somewhat more protein than does corn or wheat, is an excellent feed for the dairy cow. (223) It is shown in Appendix Table III that 100 lbs. of oats furnishes but 70.4 lbs. of total digestible nutrients, while the same weight of dent corn supplies 85.7 lbs., or 21 per ct. more. Therefore we might naturally suppose that ground corn would be decidedly more valuable than ground oats, pound for pound, in milk production, just as it is for fattening cattle, sheep, and swine. But as a result of practical experience and feeding trials, the Scandinavians rate oats as worth only 10 per ct. less than corn in their feed-unit system. (178) In one trial by Lindsey at the Massachusetts Station[8] 4.5 lbs. of oats even equalled the same weight of corn, when fed with a basal ration of 3.2 lbs. bran and 19.1 lbs. mixed hay. Doubtless the fact that oats is a bulky feed and is also richer than corn in protein gives it a higher relative value for dairy cows than for fattening stock. (649) Oats should be ground or crushed for cows.

580. Barley.—Barley is fed to dairy cows to a considerable extent in Europe and has the reputation of producing milk and butter of excellent quality. The Danes regard ground barley and oats as one of the best concentrate mixtures for dairy cows. Judging from the composition of barley and the results with other animals (226), we might think that barley would be worth slightly less than corn per pound for milk production, but the Scandinavians consider these grains of practically equal value, and in trials recently carried on at the Wisconsin Station[9] by Morrison, Humphrey and Hulce ground barley was equal to ground corn when forming 60 per ct. of the concentrate mixture. Barley should always be ground or crushed for cattle.

581. Rye.—Large allowances of rye produce a hard, dry butter, but about 2.2 to 3.3 lbs. per head daily mixed with other feed has given good results. In a trial by Hayward at the Pennsylvania Station,[10] when 3.5 lbs. of ground rye was fed in place of the same weight of ground corn as part of a balanced ration, 4 per ct. less milk and 5 per ct. less butter was produced, indicating that rye is less valuable than corn for dairy cows. (232)

[6]Me. Rpt. 1895.
[7]Friis, Copenhagen Sta., 34th Rpt., 1895.
[8]Mass. Rpt. 1913, Part I, pp. 141-153.
[9]Wis. Bul. 319, p. 68.
[10]Penn. Bul. 52.

582. Emmer.—This grain closely resembles oats in composition and in feeding value for dairy cows. In a trial by Wilson and Skinner at the South Dakota Station[11] in which emmer was compared with corn as the only concentrate, 13 per ct. more emmer was required than corn per pound of butter fat produced. Emmer should be ground for cattle. (**233**)

583. Grain sorghums.—These grains are of great importance to dairymen in the semi-arid Southwest, usually being the cheapest concentrates available. Ground kafir or milo closely approaches ground corn in value for milk production, being worth only 5 to 10 per ct. less per 100 lbs. When fed as the only concentrate with prairie, timothy, or sorghum hay or with corn fodder, the grain sorghums tend to dry up the cows, and if fed abundantly to fatten them, as would be expected from such an unbalanced ration. (**235-240**)

584. Sweet sorghum seed.—The seed from the sweet sorghums is not as valuable as kafir or milo, as it is more astringent and constipating. However, it may be fed satisfactorily as part of the concentrate mixture.[12] (**241**)

585. Dried beet pulp.—This bulky carbonaceous concentrate has become popular with dairymen, especially those feeding cows on forced test, on account of its slightly laxative and cooling effect. It is rated at 10 per ct. below corn or barley in feeding value in the Scandinavian feed-unit system, but in a brief trial by Lindsey at the Massachusetts Station[13] it was equal to corn meal when fed with a basal ration of wheat bran, cottonseed meal, and mixed hay. Since dried beet pulp often sells for a higher price than corn or other grain, it is important to bear in mind that merely as a source of nutrients for economical production, it is worth no more per ton than corn, or even less. As a part of the concentrates for cows on official test, or when a limited amount is fed with heavy feeds to make the concentrate mixture more bulky, it may be worth more per ton than corn. (**276**)

Where silage or other succulent feed is not available, dried beet pulp is a satisfactory substitute, tho usually much more expensive than silage.[14] When a large allowance is used, it should always be moistened before being fed.

586. Molasses; dried molasses-beet pulp.—In the Gulf states *blackstrap molasses* and in the western states *beet molasses* are often cheap carbonaceous feeds. They are suitable for dairy cows, as has been pointed out in Part II. (**277, 280**) In other districts a limited amount of molasses, usually blackstrap, is often used as an appetizer or is diluted and poured over rather unpalatable roughage to induce the cows to eat it with less waste. Tho the actual nutritive value of molasses is probably lower rather than higher than that of corn, pound for pound, it may be worth more than corn when thus fed in limited amounts.

[11]S. D. Bul. 81.
[12]Cook, N. J. Rpt. 1882.
[13]Mass. Rpt. 1913, Part I, pp. 129-140.
[14]Billings, N. J. Bul. 189; Foster, N. Mex. Bul. 122.

Dried molasses-beet pulp was found about equal in feeding value to dried beet pulp for dairy cows in trials by Billings at the New Jersey[15] and Lindsey at the Massachusetts Station.[16] In a trial by Billings dried molasses-beet pulp proved almost as valuable as an equal weight of hominy meal, and even more palatable. Since both dried beet pulp and molasses-beet pulp are low in protein, they should not be fed as substitutes for protein-rich feeds, as has often been done. (278)

587. Whey.—When there is more whey available than can be utilized by the swine or the calves, it may be fed to dairy cows. According to the feed-unit system 12 lbs. of whey is equal to 1 lb. of corn or barley. At the Kiel Dairy Station[17] cows were fed 11 to 22 lbs. per head daily of sweet whey with good results. Cattle will not usually drink much sour whey. (268)

II. Protein-Rich Concentrates

588. Wheat bran.—This palatable, bulky concentrate is one of the most popular feeds for the dairy cow, for it is quite high in crude protein, is rich in phosphorus, and has a beneficial laxative effect on the digestive tract. (218) Owing to its popularity, bran is often high in price, considering the amount of crude protein it furnishes. Other by-products, such as cottonseed meal, linseed meal, or gluten feed, which are richer in digestible crude protein, are then more economical sources of protein for balancing the ration. Under such conditions it is accordingly best to feed bran only in limited amount for its beneficial effect on the health of the animals and its bulk, rather than as the chief source of crude protein in the ration. This concentrate is especially valuable for cows just before and after calving, for those on official test, and for young, growing animals.

In feeding trials with 447 cows on several Danish farms the Copenhagen Station[18] found wheat bran fed as the sole concentrate fully equal to a mixture of equal parts of ground barley and oats. Bran, however, should rarely be so fed, but instead in combination with some feed rich in carbohydrates, such as corn, rye, barley, etc., and with some legume roughage to furnish lime, which it lacks. (98)

589. Wheat shorts; wheat middlings; wheat mixed feed.—Tho wheat shorts or middlings are higher in digestible crude protein than wheat bran, they are less palatable and are heavy, rather than bulky feeds. They should hence be mixed with other feeds and should not form over one-third of the concentrate mixture. The Copenhagen Station[19] secured slightly larger returns from wheat shorts than from wheat bran in trials with 240 cows. (220)

Because wheat mixed feed is higher in digestible protein and carbohydrates than bran, Smith and Beals of the Massachusetts Station[20]

[15]N. J. Rpt. 1904.
[16]Mass. Rpt. 1913.
[17]Jahresber. Agr. Chemie, 1882, p. 441.
[18]Copenhagen Sta. Rpt. 1894.
[19]Copenhagen Sta. Rpt. 1894.
[20]Mass. Bul. 146.

rate the value of a good grade of wheat mixed feed at 5 to 10 per ct. more than that of bran.

590. Corn gluten feed.—This by-product contains about twice as much digestible crude protein as wheat bran, in addition to furnishing considerably more total digestible nutrients. Also it is quite well liked by dairy cows when fed as part of a suitable concentrate mixture. It has therefore become one of the common dairy feeds. Tho it is slightly higher in total digestible nutrients than linseed meal or cottonseed meal, it furnishes only about two-thirds as much digestible crude protein. Therefore a larger amount is needed to furnish a given amount of protein, and consequently gluten feed is usually worth somewhat less per ton than those concentrates which are richer in protein. (210)

In a trial by McCandlish at the Iowa Station[21] cows were fed either 3.0 lbs. gluten feed or the same weight of linseed meal, along with alfalfa hay, corn silage, and 6.0 lbs. per head daily of a concentrate mixture of 2 parts cracked corn, 2 parts ground oats, and 1 part wheat bran. When added to this ration, which already contained a fair amount of protein, 2 per ct. more milk and 4 per ct. more fat were produced with gluten feed than with linseed meal. Had gluten feed been compared with linseed meal in a ration otherwise low in protein, it would probably have proven of lower value than linseed meal, because it contains much less protein.

Gluten feed and linseed meal were compared as supplements to a ration of ground corn, corn silage, and alfalfa or soybean hay in a trial by Caldwell at the Indiana Station,[22] the amounts of gluten feed and linseed meal being adjusted so as to furnish the same quantity of protein. When thus fed, there was no appreciable difference in the production on these supplements.

591. Gluten meal; corn bran.—But little *gluten meal* is now found on the market, as most of it is combined with corn bran to form gluten feed. (211) Gluten meal contains as much digestible crude protein as linseed meal and is satisfactory for dairy cows, but it should be fed in limited amounts, as it is a rich, heavy feed.

Corn bran was found by Lindsey at the Massachusetts Station[23] to be equal to wheat bran when fed in a ration containing ample protein. It should be remembered, however, that corn bran is much lower in protein than is wheat bran. (214)

592. Corn germ meal.—Corn germ meal, which is lower in digestible crude protein than gluten feed but quite high in fat, is a satisfactory feed for dairy cows, tho most commonly fed to swine. (212) In a trial at the Vermont Station[24] Hills found a mixture of equal parts corn germ meal and wheat bran superior to a mixture of 1 part cottonseed meal, 1 part linseed meal, and 2 parts wheat bran. Corn germ meal may become rancid when stored any great length of time.

[21]Information to the authors.
[22]Ind. Bul. 203.
[23]Mass. Bul. 186.
[24]Vt. Rpt. 1901.

593. Dried brewers' grains.—Before the advent of national prohibition dried brewers' grains were widely used for feeding dairy cows, and some are still produced as a by-product in the manufacture of near-beer, etc. Dried brewers' grains supply over 70 per ct. more digestible crude protein than wheat bran and are nearly as bulky a feed. However, they do not have the same beneficial laxative and cooling effect on the system as bran. In a trial by Lindsey at the Massachusetts Station[25] dried brewers' grains proved somewhat superior to wheat bran when fed with gluten feed, corn silage, and bluegrass hay. Hills of the Vermont Station[26] found a mixture of dried brewers' grains and wheat bran equal to a mixture of linseed meal, cottonseed meal, and wheat bran. (228)

594. Malt sprouts.—Tho rather unpalatable, malt sprouts may be successfully fed to cows when used in limited amounts and mixed with other feeds. They were often a cheap source of protein before the enactment of national prohibition decreased the supply. When over 2 lbs. daily is fed, they should be soaked before feeding in order to avoid digestive disturbances, as they swell greatly on absorbing water. Malt sprouts are low in lime. In a trial by Lindsey at the Massachusetts Station[27] 2 lbs. of malt sprouts was about equal to 1.5 lbs. of gluten feed. Feeding over 3.5 lbs. per head daily may impart a bitter, aromatic taste to the milk. When making up half to two-thirds the concentrate allowance, Hills of the Vermont Station[28] found malt sprouts of lower value than oats. (230)

595. Buckwheat middlings.—Hills of the Vermont Station[29] reports that cows fed buckwheat middlings produced 8 to 11 per ct. more milk than on an equal weight of a mixture of equal parts corn and wheat bran. When fed as the sole concentrate, the cows did not usually relish buckwheat middlings, and the quality of the butter was somewhat impaired. Hayward and Weld of the Pennsylvania Station[30] found buckwheat middlings and dried brewers' grains equally valuable for dairy cows, when judiciously fed as part of a balanced ration. When thus fed, neither of these feeds had a detrimental effect upon the flavor or quality of the milk or butter. (244)

596. Cottonseed meal.—Experience has shown that cottonseed meal may be fed to dairy cows in properly balanced rations for years with no ill effects. This is most fortunate, for this highly nitrogenous feed is usually the cheapest source of protein in the South and often likewise in the North. Since cottonseed meal is constipating, it should be fed with laxative concentrates, such as linseed meal or wheat bran, or with succulent feed, such as silage or roots. The milk of cows heavily fed on cotton seed or cottonseed meal yields a hard, tallowy butter, light in color and poor in flavor. If a moderate allowance is fed in a properly balanced ration, the quality is not impaired and may even be improved if the other feeds tend to produce a soft butter. (561) This feed is used

[25]Mass. Bul. 94.
[26]Vt. Rpt. 1903.
[27]Mass. Bul. 94.
[28]Vt. Rpt. 1902.
[29]Vt. Rpts. 1900, 1907.
[30]Penn. Bul. 41.

as the sole concentrate on many southern farms, a practice which is safe only when a limited allowance is given.

Since cottonseed meal is a highly nitrogenous, heavy feed, when a large allowance is given the meal should be mixed with feeds which are bulky and lower in crude protein. McNutt at the North Carolina Station[31] found a mixture of equal parts cottonseed meal, dried beet pulp, and dried distillers' grains highly satisfactory when fed with corn silage. A mixture of cottonseed meal, corn meal, and wheat bran was also satisfactory, but more expensive. In trials at the Mississippi Station[32] covering 6 years Moore found that feeding 5 lbs. of cottonseed meal per head daily continuously was injurious, causing inflammation of the udder and difficult breeding. With plenty of silage in winter 4 lbs. per head daily was not injurious, if good pasture was provided during the growing season so that heavy feeding of concentrates was not necessary then. (250)

In studies at the North Carolina Station[33] on the effect of cottonseed meal on the growth and reproduction of cows, Curtis and Combs have compared a ration of cottonseed meal, corn silage, and cottonseed hulls, and rations made up of cottonseed meal and the following: (1) cottonseed hulls alone; (2) cracked corn and cottonseed hulls; (3) dried beet pulp and cottonseed hulls; and (4) cottonseed hulls plus a solution of copper sulphate, which has been advocated as an antidote for the poison of cottonseed meal. In all lots except that fed silage, some of the animals died from cottonseed meal poisoning. Others became blind or aborted. These results show the necessity of feeding only limited amounts of cottonseed meal to breeding stock and especially of feeding silage to animals which are receiving heavy allowances of cottonseed meal, when not on pasture. It is best not to feed much cottonseed meal to bulls or to cows for a few weeks before freshening.

597. Cottonseed meal vs. other concentrates.—While cottonseed meal supplies slightly more digestible crude protein than linseed meal, it commonly sells for a little less per ton in the northern states. This usually makes it one of the most economical protein-rich supplements to use in balancing the rations of dairy cows. While it is not quite as palatable as linseed meal, it is well liked by cattle. As cottonseed meal does not have the laxative and conditioning effect of linseed meal, many dairymen prefer to use both of these feeds as sources of protein in a concentrate mixture, rather than to use cottonseed meal as the only supplement. Wheat bran is also an excellent feed to use along with cottonseed meal. Even tho the cost may be increased by furnishing this greater variety, this practice is probably preferable, especially for cows of high productive capacity.

In trials by Caldwell at the Indiana Station[34] choice cottonseed meal was compared with linseed meal and gluten feed as a supplement to a

[31]Proc. Amer. Soc. Anim. Prod. 1914.
[32]Miss. Bul. 174.
[33]Information to the authors.
[34]Ind. Bul. 203.

ration of ground corn, corn silage, and either alfalfa or soybean hay. The amount of each supplement was adjusted so that all rations furnished the same amount of protein. Relatively small amounts of the supplements were required to balance these rations, which were already fairly high in protein, due to the legume hay. Both with alfalfa and with soybean hay, the production of milk and of butter fat was just a trifle higher when the cottonseed meal was fed, but there was no consistent difference in the amount of dry matter in the feed required for 100 lbs. of milk or for 1 lb. of butter fat, when the different supplements were fed.

In a feeding trial with 24 cows lasting 120 days at the Virginia Station,[35] Soule and Fain found that the relative amount of digestible crude protein contained in cottonseed meal and gluten meal was a fair measure of their feeding value. Moore of the Mississippi Station[36] concluded that 1 lb. of cottonseed meal was worth as much as 1.5 lbs. of wheat bran for dairy cows.

598. Cold-pressed cottonseed cake; cotton seed.—Cold-pressed cottonseed cake was found slightly less valuable than the same weight of a mixture of 2 parts of choice cottonseed meal and 1 of cottonseed hulls in a trial by Lee and Woodward at the Louisiana Station.[37] They conclude that the chemical composition of cold-pressed cottonseed cake is a reliable indication of its feeding value. (**248**) Moore found at the Mississippi Station[38] that 100 lbs. of cottonseed meal was equal to 171 lbs. of cotton seed in feeding value for dairy cows. (**245**)

599. Linseed meal.—Without question, old-process linseed meal is one of the most valuable feeds for dairy cows. (**254**) This high rank is due not only to its richness in protein, but even more to its slightly laxative and conditioning effect, which aids in keeping stock thrifty and vigorous. For this reason, many experienced dairymen include 1 to 2 lbs. of linseed meal per head daily in the concentrate mixture they feed their cows, even when other feeds, such as cottonseed meal, are cheaper sources of protein. Linseed meal is especially valuable, due to its laxative and regulating effect, when no succulent feed is available or when hay from the grasses or dry corn forage must be fed in place of legume hay.

This feed, which is highly palatable to cattle, is greatly esteemed in fitting animals for show or sale, for it aids in producing finish and bloom and in making the hide mellow and the hair silky. It is also widely and successfully used as part of the concentrate mixture for cows on official test and in preparing cows for freshening. Van Pelt writes,[39] "Fed with ground corn, ground oats, and bran at the rate of 2 lbs. daily for 60 to 90 days prior to freshening, it develops a condition of quality and sappiness in the cow that insures successful parturition and promptness in coming to her maximum flow of milk. . . . . The

[35]Va. Bul. 156.
[36]Miss. Bul. 70; see also S. C. Bul. 117
[37]La. Bul. 110.
[38]Miss. Bul. 60.
[39]How to Feed the Dairy Cow, pp. 73-6.

careful feeder who demands uniformly large results will always keep on hand enough linseed meal, or linseed cake, so it can be used in limited amounts as occasion and necessity demand."

Due to the fact that linseed meal furnishes slightly less protein than cottonseed meal, it was found to be of slightly lower value than cottonseed meal as a source of protein in trials at the Pennsylvania,[40] Vermont,[41] and North Carolina[42] Stations. Linseed meal tends to produce a soft butter and therefore may sometimes be advantageously fed in rations which would otherwise produce a tallowy product.

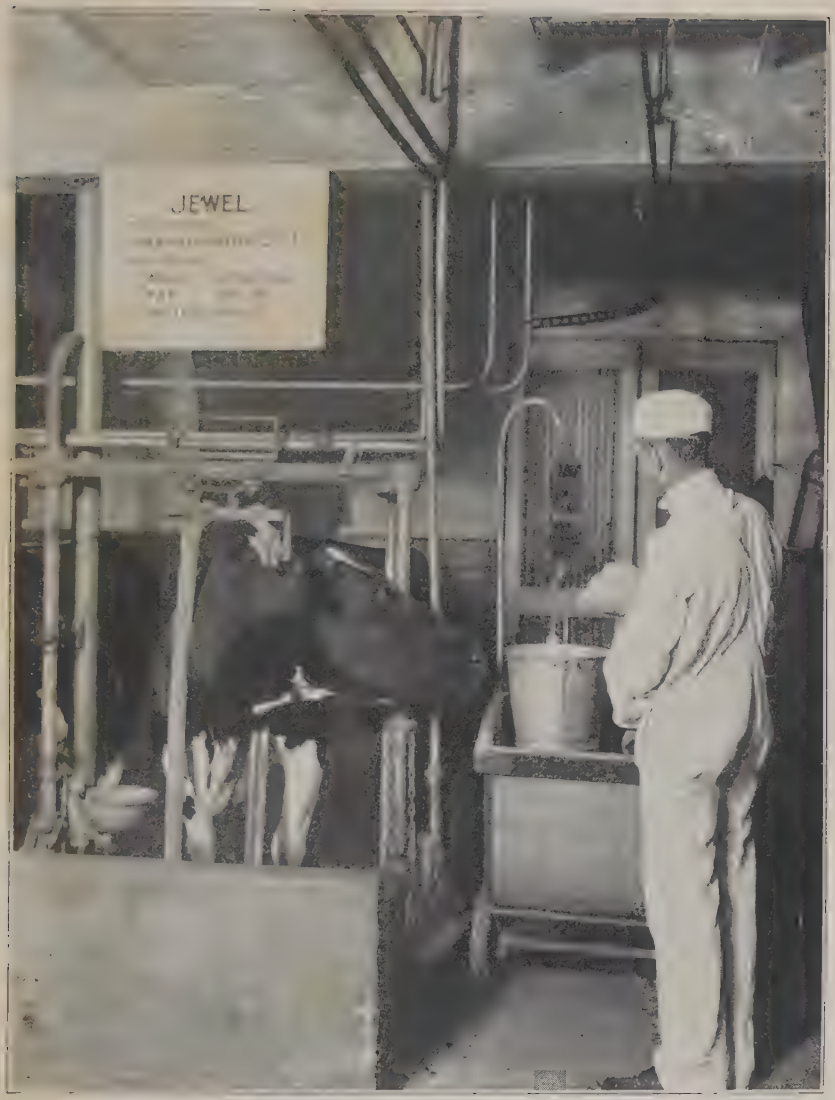
600. Soybeans.—Ground soybeans were compared with cottonseed meal in a trial by Price at the Tennessee Station,[43] 2.3 lbs. of these protein-rich supplements being added to a ration of 2.3 lbs. corn-and-cob meal, 24.1 lbs. corn silage, and 10.2 lbs. alfalfa hay. Slightly more milk and butter fat were produced when the ground soybeans were fed than when cottonseed meal was used as the supplement. Likewise at the Massachusetts and New Jersey Stations,[44] ground soybeans proved slightly superior to cottonseed meal for milk production.

Otis found at the Kansas Station[45] that when soybeans formed one-half the concentrates, the butter was so soft that it was impossible to work it satisfactorily, even tho chilled with ice water. This can be prevented by the addition to the ration of cottonseed meal, which tends to produce hard butter. (256)

601. Soybean oil meal or cake.—Soybean oil meal or cake, the by-product from the extraction of soybean oil, is well-liked by stock. It is about as high in protein as choice cottonseed meal, and the protein is slightly more digestible. Only of recent years has this valuable feed been of any importance in this country, but now considerable amounts are imported from the Orient, and oil mills in this country are taking up the crushing of soybeans for oil production. In a trial by McCandlish at the Iowa Station,[46] soybean oil meal containing 43.6 per ct. crude protein was equal in value to high-grade linseed meal, when fed as a supplement to a ration of corn silage, alfalfa hay, and a concentrate mixture of cracked corn, ground oats, and wheat bran.

In a trial by Gilchrist[47] of England, soybean cake was slightly superior to cottonseed cake for milk production, and in an experiment by Hansen[48] soybean cake and linseed cake proved practically equal in value. Tho a daily allowance of 4 to 7 lbs. of soybean cake was fed, no ill effects resulted. Lindsey of the Massachusetts Station[49] found that soybean meal from which the oil had been extracted did not modify the composition of the milk or exert a marked influence on the body of the butter. Feeding soybean oil increased the percentage of fat in the milk temporarily and produced a softer, more yielding butter. (257)

[40]Penn. Rpt. 1895.
[41]Vt. Rpt. 1907.
[42]N. C. Rpt. 33, 1910, p. 29.
[43]Tenn. Bul. 80.
[44]Mass. (Hatch) Rpt. 1894; N. J. Rpt. 1913.
[45]Kan. Bul. 125.
[46]Jour. Dairy Science, 5, 1922, pp. 27-38.
[47]Mark Lane Express, 100, 1909, p. 667.
[48]Deutsche Land. Presse, 36, 1909.
[49]Mass. Rpt. 1908.



BALANCED RATIONS ARE NECESSARY FOR PROFITS IN DAIRYING

The farmer who does not feed his cows a concentrate mixture that makes a well-balanced ration should not expect a profit. Even well-bred cows can not be expected to give a large yield of milk unless they are furnished the proper raw materials in their feed. (From Wisconsin Station.)

THE COW-TESTER FINDS THE "BOARDER" COW

Most dairy herds contain some cows that are not paying for their keep. The tester in a cow testing association soon discovers these robbers.

THE DAIRY COW BEFORE THE JURY

Even a skilled judge often makes mistakes in predicting the production of a cow from her appearance alone. However, this jury—the milk scales, the Babcock test, the milk record, and the feed book —never err in determining her actual profitableness. (From Wisconsin Station.)

602. Cocoanut meal.—Since the World War, considerable amounts of cocoanut meal (also called copra meal) have come upon American markets, both old-process meal, from which the oil has been expressed, and new-process meal, from which the oil has been extracted by naphtha. (260) As the new-process meal is much lower in fat, it is not apt to turn rancid in warm weather, which not infrequently occurs with the old-process meal unless it is thoroly dry. Cocoanut meal is somewhat laxative in its action, like wheat bran and linseed meal, but is not as palatable as these feeds. It supplies less than two-thirds as much digestible crude protein as linseed or cottonseed meal but is fully as high in total digestible nutrients. In chemical composition it resembles gluten feed, and it proved slightly superior to gluten feed in a trial by Lindsey at the Massachusetts Station.[50] In this trial the yield of milk was about the same on old-process cocoanut meal as on gluten feed, but the yield of fat was 6 per ct. higher, possibly due to the oil in the meal causing a more or less temporary increase in the fat content of the milk, a finding reported in other investigations. (560)

In a trial by McCandlish at the Iowa Station,[51] when 2.5 lbs. of either old-process cocoanut meal or linseed meal was added to a ration of corn silage, alfalfa hay, and a concentrate mixture of cracked corn, ground oats, and wheat bran, the yield of milk was 2 per ct. less on cocoanut meal, but the yield of fat 4 per ct. higher. If fed in a ration otherwise low in protein, linseed meal would in all probability have proved decidedly superior, as it is much richer in protein. A limited amount of cocoanut meal produces a firm butter of excellent quality, but when fed in excess of 3 to 4 lbs. per head daily it may make too hard a butter.

Woll [51a] reports good results in California trials where 2 to 4 lbs. of cocoanut meal was fed per head daily. The percentage of fat in the milk was increased very slightly on the cocoanut-meal rations and the milk flow was maintained well.

603. Palm-kernel meal and miscellaneous oil cakes.—European dairymen make wide use of various oil cakes, employing not only cottonseed, linseed, soybean, and cocoanut cake, but also such by-products as palm-nut, sunflower-seed, hemp-seed, and rape-seed cakes, which are practically unknown to American feeders. (259) Before the World War the palm kernels were largely shipped from Africa to Germany. During one period of the war considerable quantities were sent to America, but later the raw material was sent chiefly to England. In trials at the Kentucky Station[52] by Hooper and Nutter it was necessary to mix palm-kernel meal with other feed to teach cows to eat it. They conclude that it has about the same feeding value as wheat bran, when used as a partial substitute for this feed.

604. Velvet beans. —Velvet beans are fast becoming an important dairy feed in the South. (264, 361) The beans and pods should either

[50]Mass. Bul. 155.

[51]Jour. Dairy Science, 5, 1922, pp. 27-38.

[51a]Cal. Bul. 335.

[52]Ky. Cir. 23.

be ground, forming *velvet bean feed* (often erroneously called velvet bean meal), or the whole beans and pods should be soaked 24 hours before feeding, to soften the hard pods. Velvet bean feed or the soaked beans and pods are not very palatable to cattle, and the best results are secured when either of these feeds forms not over 40 per ct. of the concentrates, the balance consisting of better-liked feeds. Velvet bean feed furnishes slightly more digestible crude protein than wheat bran and is considerably higher in total digestible nutrients. Hooper and Nutter at the Kentucky Station[53] found velvet bean feed about equal to wheat bran when fed as a partial substitute for it. Lindsey and Beals at the Massachusetts Station[54] report it to be of slightly higher value than wheat bran, when fed in a concentrate mixture consisting of 4 parts of either velvet bean feed or wheat bran, 4 parts of corn meal or corn feed meal, and 2 parts of cottonseed meal.

Velvet bean feed is worth much less per ton than cottonseed meal, as would be expected from the fact that it supplies only 18 per ct. crude protein and contains over 12 per ct. fiber. Moore of the Mississippi Station[55] considers 1 lb. of cottonseed meal equal to 2.5 lbs. of velvet bean feed. Velvet bean feed had a slightly lower value than this in a trial by Ewing, Ridgway, and Doubt at the Texas Station,[56] while in a trial by Jarnagin of the Georgia College of Agriculture[57] velvet bean feed at $25 per ton was more economical than cottonseed meal or peanut meal at $35 per ton.

605. Dried distillers' grains.—Before national prohibition was enacted, dried distillers' grains, which are about as bulky as wheat bran and as high in protein as gluten feed, were extensively used for feeding dairy cows. At the Massachusetts Station[58] dried distillers' grains proved slightly superior to gluten feed, and at the Vermont Station[59] they proved somewhat better than dried brewers' grains and about equal to cottonseed meal. The grains chiefly made from rye are inferior to those chiefly made from corn. In some instances cows must be accustomed to the smell and taste of distillers' grains before they will take them readily, but later they prove palatable. (**283**)

606. Peanut meal; peanut feed.—With the great increase in the peanut oil industry, *peanut meal* from hulled peanuts and *peanut feed* from unhulled or partially hulled peanuts are coming to be important dairy feeds, especially in the southern states. (**258**) These feeds are palatable to cattle and are slightly laxative in their effect. In a trial at the Texas Station[60] Ewing, Ridgway, and Doubt compared peanut feed from partially hulled nuts, containing 38.2 per ct. crude protein and 11.5 per ct. fiber, with choice cottonseed meal. The peanut feed did not prove quite so valuable, pound for pound, as the cot-

[53]Ky. Cir. 23.
[54]Mass. Bul. 197.
[55]Information to the authors.
[56]Tex. Bul. 238.
[57]Ga. State Col. Agr. Bul. 159.
[58]Mass. Bul. 94.
[59]Vt. Rpt 1907.
[60]Tex. Bul. 238.

tonseed meal, but was more palatable. A mixture of peanut feed and cottonseed meal gave better results than either feed alone.

Peanut meal from hulled nuts, containing 44.4 per ct. crude protein, proved fully equal to linseed meal in a trial by McCandlish at the Iowa Station.[61] The feeding value of peanut meal and peanut feed varies widely, depending on how much hulls are present in the product. Indeed, the crude protein content will range from 44 per ct. or over in a high grade peanut meal to 28 per ct. or less in peanut feed from unhulled nuts. It is therefore important always to buy these feeds on a guarantee of chemical composition.

607. Skim milk.—Skim milk is worth much more for feeding to pigs or calves than to dairy cows, tho occasionally, when a surplus is at hand, it is thus used. (**266**) At the Connecticut (Storrs) Station[62] when sweet separator skim milk was offered to the herd of 24 cows, only 4 would drink it, even tho water was withheld for 48 hours and grain was mixed with the milk. With these 4 cows skim milk was substituted for half the concentrates in the ration at the rate of 8 lbs. of milk for 1 of concentrates. This substitution caused a small increase in the yield of milk.

608. Blood meal; flesh meal; fish scrap.—Blood meal is not commonly used for feeding dairy cows, primarily due to its high price, but it is quite extensively used in calf feeding. It is occasionally used in stimulating cows to their utmost when on test, but only 1 to 2 lbs. should be added to the ration. It is not palatable to cattle, tho they can be taught to eat it when mixed with other feeds. In a trial by Lindsey at the Massachusetts Station[63] 1.1 lbs. blood meal was equal to 2.2 lbs. cottonseed meal. (**271**)

Dairy cows may be accustomed to eating *flesh meal,* somewhat similar to the tankage or meat meal of this country, by mixing a small amount with well-liked concentrates. European investigators do not recommend feeding over 2.2 to 2.8 lbs. daily per 1,000 lbs. live weight. (**270**)

Fish meal from which the fat had been extracted proved equal to cottonseed meal in trials by Isaachsen[64] with 20 cows. Kühn[65] states that a daily allowance of 2.3 lbs. of fish scrap produced no deleterious effect on the milk. (**273**)

III. Hay from the Legumes

609. Legume hay for the dairy cow.—On most farms in the United States the Indian-corn plant provides the cheapest, most abundant, and most palatable carbohydrates the farmer can produce, but it falls short in furnishing protein, so vital in milk production. Happily, at least one of the legumes—alfalfa, clover, cowpeas, soybeans, vetch, etc.—can be grown on every American farm to supply the deficiency. The dairyman

[61] Jour. Dairy Science, 5, 1922, pp. 27-38.
[62] Conn. (Storrs) Rpt. 1904.
[63] Mass. Rpt. 1909, II. pp. 153-157.
[64] Expt. Sta. Rec. 28, p. 363.
[65] Jahresber. Agr. Chem., 1894, p. 482.

who grows great crops of corn for grain and silage must also have broad fields of clover, alfalfa, or some other legume to help round out the ration.

High in crude protein and mineral matter, especially lime, the legume hays are of great importance in reducing the amount of expensive protein-rich concentrates needed to provide a properly balanced ration for the dairy cow. The following paragraphs show that when an abundance of legume hay of good quality and silage from well-matured corn is supplied, but half as much concentrates need be fed as when only carbonaceous roughages are used. Indeed, for cows of rather low productive capacity a ration of legume hay and corn or sorghum silage alone may even be the most economical one that can be furnished. Tho the milk yield may be reduced somewhat on such a ration, an animal of this kind may not pay for the addition of any concentrates. When legume hay is fed to dairy cows, it is desirable that some succulent roughage, such as corn silage or roots, be fed in addition, to furnish greater variety and add to the palatability of the ration.

610. Alfalfa hay.—Good alfalfa hay is generally placed at the head of the list of roughages suitable for the dairy cow, on account of its high content of protein and its palatability. (338) The value of this hay in balancing rations otherwise low in protein is well shown in a trial by Caldwell at the Ohio Station[66] in which one lot of 6 cows was fed a ration of 11.6 lbs. alfalfa hay, 27.8 lbs. corn silage, and 5.9 lbs. corn meal for 56 days, in comparison with another lot fed 9.3 lbs. concentrates (consisting of one-third each of cottonseed meal, wheat bran, and corn meal) with 5.6 lbs. corn stover, and 29.3 lbs. corn silage. The ration fed Lot I cannot be called ideal, for it would have been improved had a greater variety of concentrates been fed instead of corn meal alone. Also the production would probably have been greater if a small amount of some protein-rich concentrate had been substituted for part of the corn, to provide slightly more protein than the alfalfa ration furnished. However, this lot, which was fed less than two-thirds as much concentrates as Lot II, and received no purchased protein-rich concentrates whatsoever, produced slightly more milk and nearly as much butter fat. The nutritive ratio of the alfalfa ration was 1:7.0 and of the ration containing the purchased concentrates, 1 : 5.7.

While alfalfa hay is high in protein for a roughage, containing on the average 10.6 per ct. digestible crude protein, a considerable portion of this is not true protein but consists of the compounds classed as amids. (11) Indeed, Armsby gives the digestible true protein content of alfalfa as but 7.1 per ct., only two-thirds as much as the amount of digestible crude protein. (171) On account of the difference in opinion as to whether amids can replace protein in stock feeding (94), Hart and Humphrey carried on metabolism trials at the Wisconsin Station[67] in which the crude protein in the rations fed dairy cows came either from alfalfa hay or from a mixture of corn grain, corn gluten feed, and corn

[66]Ohio Bul. 267.

[67]Wis. Res. Bul. 33.

stover. Altho in this latter ration practically all the crude protein was true protein, the crude protein in the alfalfa hay had just as high a value for milk production, notwithstanding the fact that a considerable portion was made up of the simpler compounds classed as amids.

In general, leafy, fine-stemmed, early-cut hay is preferred by dairy cows. In many sections a decided prejudice exists among stockmen in favor of a certain cutting of alfalfa. Often this is largely unwarranted, as the actual difference in feeding value may be small. For instance, on account of a wide-spread opinion among dairymen in Utah that first crop alfalfa hay was the highest in feeding value, Carroll of the Utah Station[68] compared first, second, and third crop hay in trials during 2 years. Each crop was cut at the period of early bloom from the same field and was cured in excellent condition. In order that the test might be as much as possible upon the different cuttings of hay, the cows were given all the hay they would clean up without waste, with only 0.65 lb. of concentrates daily for every pound of butter fat produced per week. In these trials the advantage of any one crop over the others was found to be almost negligible. In the corn belt and eastward quite commonly the first cutting of alfalfa is coarser and less leafy than the later cuttings, and is hence of lower value.

611. Substituting alfalfa hay for part of the concentrates.—The effective way in which alfalfa hay can be used to replace part of the concentrates in a ration for dairy cows is further shown in a trial by Fraser and Hayden at the Illinois Station,[69] in which 2 lots, each of 3 cows, were fed for two 66-day periods with the following results:

Feeding alfalfa hay in place of part of the concentrate allowance

Average ration		Average daily yield Milk Lbs.	Fat Lbs.	Nutritive ratio
Ration I				
Corn silage, 30 lbs. Clover hay, 6 lbs.	Corn meal, 6 lbs. Wheat bran, 8 lbs.	23.8	1.00	1 : 6.9
Ration II				
Alfalfa hay, 8 lbs. Corn silage, 30 lbs. Clover hay, 6 lbs.	Corn meal, 6 lbs.	24.4	0.98	1 : 7.0

Tho 8 lbs. of alfalfa hay in Ration II replaced an equal weight of wheat bran fed in Ration I, Ration II produced slightly more milk and practically as much fat.

Nearly as good results were secured in a trial by Billings at the New Jersey Station [70] in which one lot of cows was fed 14 lbs. alfalfa hay and 35 lbs. corn silage, with only 2.5 lbs. cottonseed meal for concentrates, while another lot was fed 11 lbs. purchased concentrates (cottonseed meal, dried brewers' grains, and wheat bran), with corn stover and corn silage for roughage. In this trial the 14 lbs. of alfalfa hay replaced 8.5 lbs.

[68]Utah Bul. 126. [69]Ill. Bul. 146. [70]N. J. Bul. 190.

of the protein-rich concentrates fed the second lot and also 5 lbs. of corn silage and 7 lbs. of corn stover. On this cheaper ration there were produced only 1 lb. less milk and 0.08 lb. less fat per head daily.

612. Substituting alfalfa hay for all the concentrates.—Even tho alfalfa hay excels as a roughage for dairy cows, it is nevertheless a roughage and not a concentrate. Hence, when it is substituted for all the concentrates in a ration, the production of good dairy cows will be decreased markedly. Such a ration as alfalfa hay and corn silage alone is too bulky and not rich enough in net energy for continued high production. Alfalfa hay contains about three times as much fiber as wheat bran, which is bulky for a concentrate, and furnishes but 65 per ct. as much net energy. Bearing in mind the productive capacity of his cows and the price of legume hay compared with concentrates, each dairyman must decide for himself to what extent it is economical to substitute legume hay for concentrates.

In one instance which has come to the attention of the authors, a dairyman claimed repeatedly that he could secure just as high production from a ration of good alfalfa hay and first-class corn silage as when he fed a liberal amount of concentrates. When the matter was investigated, it was found that he was supplying the cows with large amounts of very choice alfalfa hay and was not forcing them to eat it up clean, but allowing them to pick out only the leaves and tender parts. The stems were then fed to horses and other stock. This dairyman, who was following a wise farm practice, failed to appreciate that the cows were eating not alfalfa hay, but chiefly alfalfa leaves. These contain nearly as much crude protein as gluten feed, and not much more fiber than oats.

All the concentrates in a ration were replaced by alfalfa hay in a trial by Billings at the New Jersey Station.[71] In this trial a ration consisting merely of 17.5 lbs. alfalfa hay and 35 lbs. corn silage was compared with a ration containing over 9 lbs. of purchased protein-rich concentrates, fed with corn silage and corn stover. This latter ration was far from ideal, for it contained no legume hay. However, it produced over 20 per ct. more milk and butter fat than the alfalfa hay and silage ration.

At the Illinois Station[72] Fraser maintained a herd of good producing cows for 6 years exclusively on the alfalfa hay and corn silage grown on 20 acres. The average yield of milk was 3,980 lbs. and of fat 139.5 lbs. per acre. This ration did not keep the cows in as good condition as when concentrates were fed in addition, and undoubtedly a larger and also more economical yield would have been secured had at least a moderate concentrate allowance been supplied.

In a 12-week trial with 8 cows at the New Mexico Station[73] Vernon found that 246 lbs. of alfalfa hay fed alone, or 202 lbs. of alfalfa hay and 49 lbs. of wheat bran, produced 100 lbs. of milk. The cows yielded more

[71]N. J. Bul. 204. [72]Information to the authors. [73]N. Mex. Rpt. 1904.

milk on the bran-alfalfa ration, but the increase was dearly purchased under New Mexico conditions where concentrates are very high in price compared with alfalfa hay.

In some sections of the West, owing to the cheapness of alfalfa hay, dairy cows are given this feed alone, possibly with green alfalfa soilage or pasture in addition during the summer. Woll of the California Station[74] found in trials in which rolled barley was added to an exclusive alfalfa ration that the immediate increase in production resulting from grain feeding was not sufficient, with feeds at prevailing prices, to pay for the added expense. However, considering the influence on the production during the balance of the lactation period and the effect on the condition of the cows, he believes that the feeding of some grain is advisable, especially in the case of high producing animals or heifers in milk. Balancing the alfalfa hay by the use of corn or milo silage also increased the production and was more economical than feeding grain, except for high producing animals, which should have some concentrates to keep up a large production.

613. Alfalfa meal.—It has been previously pointed out that grinding alfalfa hay to a meal will not transform a hay into a concentrate, and that we would hardly expect alfalfa meal to have as high a value as wheat bran, since it contains 3 times as much fiber and but about 85 per ct. as much digestible crude protein. (**339, 344**) In trials by Hills at the Vermont Station,[75] by Mairs at the Pennsylvania Station,[76] and by Lindsey at the Massachusetts Station,[77] when alfalfa meal was substituted for the same weight of wheat bran, the milk yield was reduced 3 to 6 per ct. More recently Snyder has reported chopped alfalfa as being equal to wheat bran in trials at the North Platte, Nebraska Sub-Station,[78] perhaps due to a superior quality of chopped alfalfa hay being used. Taking the results as a whole, we may conclude that in view of the palatability of alfalfa hay to dairy cows and its thoro mastication during rumination, the use of alfalfa meal is ordinarily not economical when good alfalfa hay is available.

614. Clover hay.—Hay from the clovers, cut while yet in bloom, is one of the best roughages for dairy cows. By the use of clover hay—red, alsike, or crimson—the dairyman may reduce the amount of concentrates needed to supply a well-balanced ration in the same manner as has been shown in the case of alfalfa hay. (**347, 350, 353**) The relative value of red clover and alfalfa hay is a question which is often discussed. Alfalfa hay is considerably richer in digestible protein than red clover hay. On the other hand, it does not furnish quite as much net energy as clover, according to Armsby. (**171**) We might suppose, therefore, that alfalfa would be superior to clover when fed in a ration otherwise low in protein, but that it might show no superiority over

[74] Cal. Buls. 256, 282.
[75] Vt. Rpt. 1906.
[76] Penn. Bul. 80.
[77] Mass. Rpt. 1909, Part II, pp. 158-166.
[78] Nebr. Bul. 164.

clover when an abundance of protein is furnished by the other feeds in the ration.

Alfalfa hay was compared with red clover hay for dairy cows in 4 trials by Hayden at the Ohio Station.[79] In these trials, on both the alfalfa and the clover rations the cows were allowed to consume as much feed as they would eat, instead of the amounts being kept the same for both lots. When fed alfalfa hay, the cows consumed 8 per ct. more concentrates (corn and wheat bran), 9 per ct. more corn silage, 11 per ct. more corn stover, and 15 per ct. more hay than when fed clover hay. The alfalfa hay therefore seemed to be a better appetizer than clover. The cows also yielded 9.3 per ct. more milk and 7.5 per ct. more butter fat on alfalfa than on clover, due either to the larger amount of feed eaten or to the fact that the alfalfa ration was better balanced, supplying more protein. On alfalfa the cows also maintained their weights slightly better.

In metabolism trials by Hart and Humphrey at the Wisconsin Station,[80] high producing dairy cows lost nitrogen steadily from their bodies and decreased in milk yield markedly on a ration of red clover hay, corn silage, and corn, oats, or wheat, or a mixture of the three grains. This was due to the fact that this ration was too low in protein to meet the demands for milk production. On the other hand, when alfalfa hay was fed in place of clover hay, the cows remained in nitrogen balance, due to the fact that the alfalfa hay was richer in protein.

615. Crimson clover hay; sweet clover hay.—The value of *crimson clover hay* as a substitute for purchased protein-rich feeds is shown in a trial by Lane at the New Jersey Station[81] in which a ration of 16.4 lbs. crimson clover hay and 30 lbs. corn silage was compared with a ration of 11 lbs. of purchased concentrates (wheat bran and dried brewers' grains), 5 lbs. mixed hay, and 30 lbs. corn silage. The yield of milk was 3.7 lbs. and of butter fat 0.15 lb. less per head daily on the crimson clover hay ration than on that containing the liberal allowance of purchased concentrates. However, the milk was produced more cheaply on the home-grown ration. (**353**)

Sweet clover hay, when well cured and not too coarse and stemmy, is satisfactory for dairy cows. It is fully as high in digestible protein as is alfalfa hay. (**352**)

616. Cowpea hay.—In the South the cowpea vine, thriving on all types of soil, is of great importance to the dairy industry, as it furnishes palatable hay, which is even richer than alfalfa in protein. (**357**) For milk production cowpea hay is far superior to such protein-poor roughages as cottonseed hulls, corn fodder, crab grass hay, or Johnson-grass hay. In a trial by Wing at the Georgia Station[82] cows fed cowpea hay

[79]Ohio Bul. 327.

[80]Jour. Biol. Chem., 38, 1919, pp. 515-27; 44, 1920, pp. 189-201; information to the authors.

[81]N. J. Bul. 161.

[82]Ga. Bul. 49.

CONTENTED COWS WITH MANGERS FULL OF ALFALFA HAY

Alfalfa hay is unexcelled as a roughage for dairy cows, because it is not only high in protein and rich in lime, but also because it is exceedingly palatable. The farmer who provides alfalfa for his herd can save much purchased concentrates.

RED CLOVER FOR HAY AND CORN FOR SILAGE MEAN PROFITS

The dairyman who has an abundance of clover or alfalfa hay and plenty of corn for silage has the foundation of an economical, efficient ration for his herd. (From Wisconsin Station.)

LUXURIANT PASTURE IS UNEXCELLED FOR DAIRY COWS

Not only is the supply of nutrients liberal on good pasture, but also the feed is succulent and palatable. Furthermore, good pasturage is rich in protein, mineral matter and vitamines.

FEEDING GREEN CORN TO KEEP UP THE MILK FLOW

If additional feed is not supplied when pastures become parched in mid-summer, the milk flow will surely decrease and it will not be possible to bring the cows back to their normal yield even should the pastures improve later.

for roughage produced 30 per ct. more milk than with cottonseed hulls as the roughage.

Just as with alfalfa hay, fair production can be secured when only cowpea hay and corn silage are fed, with no concentrates in addition. For example, in a brief trial by Lane at the New Jersey Station,[83] cows fed only 17 lbs. cowpea hay and 36 lbs. corn silage per head daily yielded 23.7 lbs. milk and 0.92 lb. fat on the average. When fed 5 lbs. corn stover and 36 lbs. corn silage for roughage, with 9 lbs. of purchased concentrates in addition, 2 lbs. more milk and 0.13 lb. more fat were produced per head daily. With cows of good productive capacity it will ordinarily pay to feed a fair concentrate allowance in addition to cowpea hay and silage, especially when the after effect on the animals of feeding concentrates is considered.

In a trial by Duggar at the Alabama Station[84] cowpea hay proved a satisfactory substitute for wheat bran when added to a basal ration of 9.6 lbs. cottonseed hulls, and 9.6 lbs. of a mixture of 2 parts cotton seed and 1 part each of wheat bran and cottonseed meal. This shows that where there is a fair supply of rich concentrates, it is more economical to complete the ration with some protein-rich roughage, like cowpea hay or cowpea silage, rather than by adding more expensive concentrates.

617. Soybean hay.—Soybean hay is becoming of much importance for the feeding of dairy cows in many districts of the country. (**358**) The hay is slightly higher than alfalfa in protein, but it is coarser, and the stems are often somewhat woody. Therefore there is usually more waste in feeding it than in feeding alfalfa. In a trial at the Indiana Station[85] Caldwell compared soybean hay with alfalfa hay, when fed in addition to corn silage and concentrates. The average daily yield of milk was 19.6 lbs. and of fat 0.90 lb. on alfalfa hay, while on soybean hay the yield of milk was 18.4 lbs. and of fat 0.86 lb. The average feed cost of 100 lbs. milk was 8 per ct. higher on soybean hay than on alfalfa hay, with both kinds of hay valued at the same price per ton. This trial shows that while soybean hay is a very good roughage for dairy cows, its value is slightly less per ton than that of alfalfa hay.

618. Field pea hay.—Hay from Canada field peas or from the popular combination of field peas and oats makes good roughage for dairy cattle. Field pea hay is even richer in protein than alfalfa hay, and oat and pea hay usually furnishes slightly more digestible crude protein than red clover hay, tho it is not so palatable. (**355**)

619. Vetch hay; lespedeza hay.—*Hairy vetch* and *common vetch* both make palatable hay for dairy cows, even higher than alfalfa hay in digestible crude protein and total digestible nutrients. (**359**)

Lespedeza hay, which resembles red clover hay in protein content, is fine-stemmed and leafy. In the South it is a popular hay for dairy cattle. (**360**)

[83]N. J. Bul. 174. [84]Ala. Bul. 123. [85]Ind. Bul. 203.

IV. Carbonaceous Roughages

620. Corn fodder.—Tho inferior to corn silage, good corn fodder, especially that from thickly planted corn, is relished by cows and is a satisfactory substitute for hay from the grasses. (**302**) Instead of being fed as the sole roughage, it should preferably be used with legume hay. In a trial by Hunt and Caldwell at the Pennsylvania Station[86] corn fodder proved almost as valuable as the same weight of timothy hay. Two tons of timothy hay per acre is a high return, while the yield of the fodder corn used in this trial was nearly 4.5 tons per acre, or over twice that of the timothy hay.

621. Corn fodder with alfalfa hay.—The value of corn fodder when fed in combination with legume hay is shown in trials by Linfield at the Utah Station.[87] Averaging together the results of 4 trials, we find that cows fed a ration of 8.7 lbs. corn fodder, 11.5 lbs. alfalfa hay, 3 lbs. of wheat bran, and 3 lbs. of either wheat, barley, or corn meal produced about as much milk and butter fat as when the same concentrates were fed with 21.5 lbs. alfalfa hay for roughage. When combined with alfalfa hay, a limited amount of corn fodder was worth as much as the alfalfa hay, pound for pound.

622. Corn stover.—Bright, well-cured corn stover is a fairly palatable feed for cattle. Tho it is too low in nutrients to form the chief part of the roughage allowance for high-producing cows, a limited amount of good stover may often be fed with economy, even to dairy cows. (**304**) In trials by Henry at the Wisconsin Station[88] 1 ton of mixed clover and timothy hay proved equal to 3 tons of uncut corn stover, and 1 ton of clear clover hay was somewhat more valuable than 3 tons of stover. Thirty-four per ct. of the coarse, uncut stover was left uneaten in these trials. If the stover had been shredded, considerably less would have been wasted. (**305**) As is pointed out later, corn stover silage (made from field-cured stover) is much more palatable than dry corn stover and is consumed with much less waste. (**632**)

623. Timothy hay.—While timothy hay is a standard and most satisfactory roughage for the horse, it is unsatisfactory for the dairy cow. It lacks protein, is not very palatable to cows, and has a constipating effect quite opposite to the beneficial action of legume hay. (**312**) The value of mixed clover and timothy hay for cows will depend on the proportion of clover present.

To demonstrate the poor results secured when timothy hay is fed with other feeds likewise low in protein, Fraser and Hayden of the Illinois Station[89] conducted a trial on a dairy farm in which 2 lots each of 8 cows were fed by the reversal method for two 42-day periods. The cows were given 12.5 lbs. per head daily of a concentrate mixture of 2.5 parts corn meal and 1 part wheat bran, with the roughages shown in the table:

[86] Penn. Rpt. 1892.
[87] Utah Bul. 68.
[88] Wis. Rpt. 1884.
[89] Ill. Bul. 146.

Timothy hay vs. alfalfa hay when fed with protein-poor feeds

	Average roughage allowance	Average daily yield of milk Lbs.
I.	Timothy hay, 10 lbs. Corn stover, 10 lbs.	23.4
II.	Alfalfa hay, 10 lbs. Corn stover, 10 lbs.	27.5

When fed the alfalfa-hay ration, which had a nutritive ratio of 1 : 6.6, the cows produced 17.5 per ct. more milk than on the unbalanced timothy-hay ration, the nutritive ratio of which was 1 : 10.2. The timothy-fed cows lost in weight and were in poor condition generally, a number being "off feed" at times. This trial shows clearly that when timothy hay must be fed it should be supplemented by concentrates high in protein.

624. Prairie and marsh hay.—The value of prairie hay and marsh hay varies widely, depending on the varieties of grasses of which it is composed. From two trials at the Minnesota Station[90] Haecker concluded that good, upland prairie hay, like that of the Minnesota region, is equal to timothy hay for dairy cows. Marsh hay ordinarily has a lower value, and is not at all well suited for feeding dairy cattle. (325)

Hay from the salt marshes near the New England Coast was found 10 to 18 per ct. less valuable than average mixed hay in trials by Lindsey at the Massachusetts Station.[91]

625. Bermuda hay.—Lloyd of the Mississippi Station,[92] studying the returns from a herd of 30 to 60 cows during 3 years, concludes that Bermuda hay equals timothy hay for milk and butter production. (320)

626. Johnson-grass hay.—Moore of the Mississippi Station[93] found Johnson-grass hay nearly as valuable as cowpea hay when corn silage, cottonseed meal, and wheat bran were the other feeds given. Had less rich and palatable concentrates been fed, it would probably have been worth but half to two-thirds as much as cowpea hay. (321)

627. Straw; oat feed; hydrolized sawdust.—Tho large amounts of *straw* can not be fed to the hard-working dairy cow, some straw, especially oat straw, may often be economically fed. When bright straw is used for bedding it is a good plan to place the straw in the manger first and allow the cows to pick it over and eat what they will, before throwing it under them for bedding. Quite commonly they will consume considerably more than many feeders would expect. Legume straw, when well cured, is of higher value than straw from the cereals. (328-9)

Oat feed is discussed under roughages instead of under concentrates, due to the fact that the usual "mill run" oat feed is distinctly a roughage, and not a concentrate. On the average, it consists of about 80 per ct. oat hulls and only 20 per ct. of the more valuable by-products of the kernel (oat dust and middlings). Such feed falls a little below hay in digestibility, but in experiments by Lindsey and Beals at the

[90] Minn. Buls. 35, 67.
[91] Massachusetts (Hatch) Bul. 50.
[92] Miss. Bul. 70.
[93] Miss. Rpt. 1895.

Massachusetts Station[94] when 7 to 8 lbs. of dry matter in oat feed was substituted for an equal amount of dry matter in mixed hay, slightly more milk was produced. We may conclude that while such oat feed has a distinct feeding value, it is not worth appreciably more per ton than mixed grass and clover hay. (224)

Hydrolized sawdust, prepared by heating sawdust with dilute acid under pressure, so that a part of the woody fiber is changed to sugar, has been successfully used as one-fourth to one-third of the concentrate mixture in trials by Morrison, Humphrey, and Hulce at the Wisconsin Station.[94a] When fed in these proportions and mixed with well-liked concentrates, there was no difficulty in getting the cows to eat the treated sawdust. In these trials 2 lbs. of hydrolized sawdust was equal in net energy value to 1 lb. of ground barley or corn. At present prices for farm grains there is little probability that such treated sawdust will be of any importance as a live stock feed, except possibly in certain districts where carbohydrate-rich feeds are unusually high in price.

628. Cottonseed hulls.—Cottonseed hulls contain a fair amount of digestible carbohydrates, but they are very low in crude protein and are rather unpalatable to cows. Southern dairymen can supply roughage for their herds more cheaply in the form of corn silage than by buying cottonseed hulls. Silage is also more palatable and stimulates a larger flow of milk. Tho experiments at the southern stations[95] have shown that good corn stover is worth more per ton than cottonseed hulls, southern dairymen often leave the corn stalks in the field and purchase the hulls for roughage. (251)

In trials at the Mississippi Station[96] Moore found that it took 100 lbs. of cottonseed hulls to equal 67 lbs. of prime Johnson-grass hay. In a trial by Soule at the Texas Station[97] cottonseed hulls were nearly equal in feeding value to sorghum hay.

V. Succulent Feeds

Succulent feeds are of even more importance in the feeding of dairy cows than of the other farm animals. In fact succulent feeds are well nigh essential to the economical production of milk in most dairy districts. Due to their cooling, slightly laxative action, such feeds aid greatly in keeping the digestive tracts of these hard-working animals in good condition. Furthermore, succulent feeds are usually highly palatable and thus they whet the appetite, so that larger amounts of roughage are consumed than if only hay and other dry forage were fed. As a result, the cows have more nutrients available for milk production, after the maintenance needs of their bodies have been met.

629. Corn silage.—Thruout the chief dairy sections of the United States corn silage is the cheapest succulent feed available, as well as

[94]Mass. Bul. 200.
[94a]Wis. Buls. 323, pp. 5-7; 339, pp. 132-3.
[95]S. C. Bul. 66; N. C. Bul. 199.
[96]Miss. Rpt. 1903.
[97]Texas Bul. 47.

the most satisfactory. (296-9) So abundantly has the high value of silage been demonstrated, that in the leading dairy districts a dairyman usually apologizes if he does not have a silo on his farm. Not only does corn silage furnish a steady and uniform supply of high quality succulent feed for winter, but large numbers of progressive dairymen have found that silage is much more economical than soiling crops to feed in summer when pastures become parched and scanty, provided only that a sufficient number of cows are fed to keep the silage from spoiling. (417)

The daily allowance of silage commonly fed ranges from 20 to 40 lbs. per 1,000 lbs. live weight. A common rule is to feed 3 lbs. of silage and 1 lb. of dry roughage per 100 lbs. live weight.

Due largely to the fact that the silage made during earlier years was frequently of poor quality and fed in a careless manner, a widespread belief existed that silage injured the flavor of the milk. For many years the largest milk condensing company in the country prohibited the use of silage by its patrons. Experience has now abundantly demonstrated that when good silage is fed under proper conditions the quality of the milk is improved, rather than impaired, and even the milk condensing factories no longer object to its use. Like other feeds, silage may be abused. Only good silage should be used, and this should be fed after milking and be eaten up clean at each feed, none being left scattered on the floor of the stable, the air of which should be kept pure and wholesome by proper ventilation. If the silage is first class and the barn is well ventilated, silage may even be fed before milking, without injuring the flavor of the milk.

It has been pointed out previously that silage from corn cut at the glazing or dent stage is more valuable than that from more immature corn. This is shown in a trial by White at the Connecticut (Storrs) Station[97a] in which silage from a late maturing variety of corn, cut in the early dough stage, was compared with silage from a variety that would mature in the usual Connecticut season. This corn was cut when it was nearly ripe and the lower leaves had turned brown. The silage from the early corn contained 29.8 per ct. dry matter, while that from the late corn contained only 20.5 per ct. In order to maintain the live weights of the cows and keep up equal production of butterfat, it was necessary to feed 1.6 lbs. more concentrates per head daily with the immature silage than with the silage from the early corn.

630. Corn silage vs. fodder corn.—Tests of corn silage and field-cured fodder corn at the Vermont[98] and Wisconsin[99] Stations were conducted in the following manner: Two rows of maturing corn extending across the field were placed in shocks, while the next 2 rows were run thru the feed cutter and placed in the silo. By thus alternating until the silo was filled, substantially equal quantities of material having the same composition were obtained as silage and shock corn, respectively. The

[97a]Information to the authors. [98]Vt. Rpt. 1891. [99]Wis. Rpt. 1891.

field-cured fodder, after being run thru the cutter, was fed in opposition to the silage to dairy cows along with equal quantities of hay and grain.

At the Vermont Station the green fodder corn, converted into silage and fed with hay and grain, produced 11 per ct. more milk than the same amount of dried corn fodder fed with the same allowance of hay and grain. In the Wisconsin trial the corn crop produced 243 lbs., or 3 per ct., more milk per acre when fed as silage than when fed as dried corn fodder.

In the following table are summarized the results of these and other trials in which the amount of milk produced from 100 lbs. of total dry matter in rations containing silage or corn fodder was determined:

Corn silage vs. fodder corn for milk production

Station and number of trials	Milk from 100 lbs. dry matter	
	Silage ration Lbs.	Fodder ration Lbs.
Wisconsin (Rpt. 1888), 3 trials	104.2	95.8
Wisconsin (Rpt. 1889), 3 trials	110.5	104.8
Vermont (Rpt. 1892), 1 trial	82.0	76.5
Pennsylvania (Rpt. 1890), 1 trial	111.9	106.3
New Jersey (Bul. 122), 1 trial	116.2	103.0
Average of 9 trials	106.0	98.6

Averaging these trials we find that 7.4 lbs. more milk was produced from 100 lbs. of dry matter in the silage rations than in the rations containing fodder corn. The higher value of the silage is not due to any increased digestibility of the silage over well-cured dry fodder, for we have seen that, on the average, corn silage is no more digestible. (298) The superiority of silage is largely due to the fact that while good-quality silage is eaten with little or no waste, a considerable part of the corn fodder is usually left uneaten. As a matter of fact, various trials show that the dry matter of that part of the corn fodder which is actually consumed may have just as high a nutritive value as an equal weight of dry matter in corn silage.[100] It has been pointed out in a previous chapter that less of the nutrients in the corn crop are lost when it is ensiled than when it is cured as dry corn fodder. Another reason why silage gives better results than dry corn fodder is that cows given this succulent, palatable feed usually consume a heavier ration than those fed the dry fodder. Hence they have a larger amount of nutrients available for milk production after the maintenance requirements of the body have been met.

631. Corn silage vs. hay.—In spite of the great importance of corn silage for feeding dairy cows, relatively few experimental data are available to show the actual comparative value of corn silage and hay for milk production. In a trial with 6 cows at the Vermont Station,[101] Hills found that when corn silage was substituted for mixed timothy,

[100]Wis. Rpts. 1890, 1891.

[101]Vt. Rpt. 1901.

red top, and clover hay at the rate of 3.5 lbs. silage for 1 lb. of hay, the milk yield was increased 7 per ct. Silage would have been slightly more economical at $4.50 per ton than hay at $15 per ton. In a trial at the Maine Station[102] Jordan found that when cows were changed from mixed hay (mostly timothy) as the only roughage to both hay and silage, the amount of concentrates remaining the same, the milk yield increased 7 per ct. When changed back to hay as the only roughage, it decreased 8 per ct. The silage used was watery, containing but 16.7 per ct. dry matter, while average silage from well-matured corn contains 26.3 per ct. dry matter. From the data secured by Jordan it is fair to conclude that had the silage been of average quality, 280 lbs. of silage would have been slightly superior to 100 lbs. of hay.

The relative value of corn silage and alfalfa hay was studied by Carroll at the Utah Station[103] in a trial in which cows were fed either alfalfa hay or both alfalfa hay and corn silage, with 4 lbs. of a concentrate mixture of equal parts wheat bran and rolled barley. When fed silage, the cows yielded 2 per ct. more milk and 4 per ct. more fat, but were given 2.5 per ct. more grain. With alfalfa hay at $15 per ton and concentrates at $30 per ton, the silage was worth $6.02 per ton. In other terms, 250 lbs. of silage was worth as much as 100 lbs. of alfalfa hay. In trials by Foster and Meeks at the New Mexico Station[104] it required 3 tons of good corn silage to replace 1 ton of choice alfalfa hay, and the milk production was no greater when silage and alfalfa hay were both fed as roughage than when the alfalfa hay was the only roughage.

From these trials we may conclude that about 250 to 300 lbs. of good corn silage is worth as much as 100 lbs. of hay for feeding dairy cows. In the feed unit system as revised by Woll, the value of corn silage for dairy cows is placed at one-third that of alfalfa or clover hay and one-half that of timothy hay per pound. (178) According to the Armsby energy values, 243 lbs. of good corn silage equals 100 lbs. of red clover hay in net energy content. (171)

632. Corn stover silage.—Silage made from cured corn stover, after all the ears have been removed, is obviously a feed relatively low in digestible nutrients, and thus is worth far less than normal well-eared corn silage, especially for high-producing animals like good dairy cows. Yet it is much preferable to dry shredded or cut corn stover, for it is more palatable and is consumed with comparatively little waste. In a trial by Morrison, Humphrey, and Hulce at the Wisconsin Station[105] normal corn silage was compared with well-preserved corn stover silage in a trial with 2 lots each of 4 cows fed by the reversal method. The cows were fed either corn silage or corn stover silage, along with alfalfa hay and a well-balanced concentrate mixture, consisting of ground corn, wheat bran, linseed meal, and cottonseed meal. On each ration the cows were fed all the silage—either corn silage or corn stover silage—they

[102] Me. Rpt. 1889.

[103] Information to the authors.

[104] N. Mex. Bul. 122.

[105] Wis. Bul. 323, p. 5.

would clean up, the amount of the other feeds being kept the same for the two lots. The cows took to the corn stover silage quite readily but consumed five pounds less a head daily, showing that it was somewhat less palatable than normal corn silage. The corn stover silage contained 73 per ct. of water, which is about the same amount as average normal corn silage.

When fed corn stover silage, the cows gave an average yield of 24.5 lbs. milk and 0.98 lb. butter fat daily. On normal corn silage they yielded 27.4 lbs. milk and 1.05 lbs. butter fat. Taking into consideration the reduced yield on corn stover silage, and the consequent larger amount of the other feeds in the ration required per 100 lbs. of milk produced, it was worth 61 per ct. as much per ton as the normal corn silage in this trial. Unless corn stover silage is of excellent quality, its value would be even lower than was secured in this trial.

As has been pointed out elsewhere, there is no advantage, compared with ensiling the entire corn plant, in removing the ears before ensiling corn fodder; then curing the ears and feeding the grain later with the stover silage. (301, 781)

633. Silage from the sorghums.—Next in value to corn silage is that from the grain and the sweet sorghums. Reed and Fitch found kafir silage practically equal to corn silage when fed with hay and grain in a trial at the Kansas Station.[106] In each of 2 trials the cows produced 3 per ct. more milk and 1 per ct. more fat when fed corn silage than when fed silage from sweet sorghum, showing this silage to be but little inferior to that from the corn plant. (309) Thruout a large part of the southern plains states, sorghum silage is a much more economical feed than corn silage, for the yield per acre is materially larger.

634. Silage from the legumes.—Tho there is far less certainty of securing silage of good quality from clover or alfalfa than from corn and the sorghums, these legumes are sometimes ensiled, especially when the weather does not permit making them into satisfactory hay. (342, 348) In each of 3 years Clark ensiled red clover at the Montana Station[107] and fed the silage to dairy cows in comparison with clover hay. When from 32 to 43 lbs. of clover silage was fed per head daily with clover and timothy hay and concentrates, 233 lbs. of the silage proved equal to 100 lbs. of good clover hay. On the silage ration the yield of milk was increased 5.7 per ct. and of fat 4.3 per ct. Clark reports that the cows relished the silage during the winter months, but that in summer it became darker in color and acquired a strong odor, a point also observed by Reed at the Kansas Station[108] with alfalfa silage. Such combinations as field peas with oats, soybeans or cowpeas with corn or the sorghums, and vetch with oats, wheat, or barley, make satisfactory silage.

Pea vines from which the green peas have been removed for the canning factory make a highly nutritious silage for dairy cattle, and one which is widely used by farmers raising peas for canning purposes.

[106]Kan. Cir. 28. [107]Mont. Bul. 94. [108]Hoard's Dairyman, 47, 1914, p. 889.

The odor of such silage is somewhat strong, but does not injure the flavor of the milk if fed after milking. (**356**)

While soybeans or cowpeas alone do not make satisfactory silage, these crops when mixed with either corn or the sorghums make an excellent silage, considerably richer in protein than corn silage. For this purpose the legume and non-legume may be grown together or they may be mixed at the time of ensiling. (**357-8**) Such mixtures as field peas and oats, and vetch with oats, wheat, or barley also make satisfactory silage. (**355, 359**)

The value of such protein-rich silage is well shown in a trial by Williams at the Ohio Station.[109] One lot of 4 cows was fed a ration of 13.5 lbs. concentrates (6 lbs. bran, 2.5 lbs. linseed meal, and 5 lbs. corn) with corn stover and mixed hay for roughage. In place of much of the concentrates, another lot was fed mixed silage made of about one-third soybeans and cowpeas and two-thirds rather immature corn. They received only 2 lbs. linseed meal and 2 lbs. bran per head daily, with 58 lbs. silage and 6.8 lbs. mixed hay. During the 4-month trial the cows fed the silage with the small amount of concentrates produced 16 per ct. more milk and 28 per ct. more fat than on the more expensive ration.

In trials by Bechdel at the Pennsylvania Station[109a] good corn silage produced 10 per ct. more milk than oat and pea silage. However, the oat and pea silage was considered a valuable summer silage that would help out in some sections during the late summer months when pasture was short and the corn silage supply was exhausted.

Bechdel found mixed soybean and corn silage, containing about 30 per ct. by weight of soybean forage, only slightly superior per ton to corn silage, even in a ration containing only a medium amount of protein.

635. Apple-pomace silage.—Hills[110] fed cows daily allowances of 24 to 35 lbs. of apple-pomace silage—as much as they would eat—in addition to 8 lbs. of grain and 10 to 12 lbs. of hay. On apple-pomace silage the cows consumed somewhat more dry matter than those getting corn silage, with a corresponding increase in milk flow. The apple-pomace silage had no deleterious influence on the cows or their milk. (**385**)

636. Sunflower silage.—As occurs with most new crops, many extravagant claims concerning sunflowers for silage have recently been made by enthusiastic advocates who have perhaps been dazzled by the luxuriant growth of the mammoth plants. Quite widely diverse results have been secured by the experiment stations and by farmers with this new silage crop. Without question, sunflowers usually produce a greater tonnage of silage per acre than corn, but the silage is less nutritious, because it carries but little grain. In digestion experiments by Sotola at the Washington Station[111] sunflower silage was found to contain only 12.6 lbs. total digestible nutrients, and in trials by Joseph and Blish at the Montana Station[111a] but 12.2 lbs. total digestible nutrients per 100 lbs.

[109]Ohio Bul. 155. [110]Vt. Rpt. 1903. [111]Wash. Bul. 161.
[109a]Information to the authors. [111a]Mont. Bul. 134.

Compared with this, silage from well-matured corn contains 17.7 lbs. total digestible nutrients per 100 lbs., or over 40 per ct. more.

In a trial by Anthony and Henderson at the West Virginia Station,[112] sunflower silage did not maintain milk production quite so well as corn silage, but was consumed readily after the cows became accustomed to it. Sunflower silage proved satisfactory in trials by Arnett, Joseph, and Tretsven at the Montana Station,[113] 283 to 375 lbs. of sunflower silage being equal to 100 lbs. of alfalfa hay. At the Washington Station[114] it was found that sunflower silage was much less palatable than corn silage. Silage from sunflowers which had been damaged considerably by rust and aphis proved decidedly unpalatable in a test by Morrison, Humphrey and Hulce at the Wisconsin Station,[115] and cows which were accustomed to good corn silage could not be forced to eat it. The following year, the silage was apparently of good quality, but considerable trouble was experienced in getting the cows to eat the sunflower silage, unless it was mixed with corn silage. In trials at the Michigan and Pennsylvania Stations[115a] sunflower silage proved decidedly less valuable than good corn silage. (384, 783)

From the results which have been secured thus far, it appears doubtful whether sunflowers will materially displace corn or the sorghums, where good yields of these excellent silage crops can be secured. In districts where the growing season is short, sunflowers for silage undoubtedly have a place among economical crops.

637. Other silage studies.—*Rye silage* was found by Hills of the Vermont Station[116] to be drier and less readily eaten than corn silage, and it made 10 per ct. less milk and butter. Cows changed from corn to rye silage shrank 20 per ct. in milk, while on changing back from rye to corn they gained 2 per ct. (318) *Millet silage* or *hay* is inferior to good corn silage. (317)

Sudan grass silage was found by Woll at the California Station[117] to be worth only 10 per ct. less than corn silage.

In experiments by the United States Department of Agriculture[118] corn silage was compared with *potato silage*, made by chopping potatoes in a special machine, and mixing with the macerated potatoes 2 per ct. by weight of corn meal to inoculate the potatoes with lactic acid bacteria, so the material would undergo the proper fermentation. (Corn meal normally contains an abundance of these bacteria.) This potato silage was about equal to good corn silage and was well-liked by the cows after they became used to it.

638. Roots.—Tho roots are excellent for dairy cows, they are little used in this country, because corn silage furnishes much cheaper succulence. Nearly 90 per ct. of the dry matter in roots is digestible, and

[112]W. Va. Cir. 32.
[113]Mont. Bul. 131.
[114]Wash. Bul. 158.
[115]Wis. Bul. 319, p. 24; Bul. 323, p. 84; unpublished data.
[115a]U. S. Dept. Agr. Bul. 1045.
[116]Vt. Rpt. 1907.
[117]Cal. Bul. 282.
[118]Information to the authors.

only 66 per ct. of that in corn silage. Yet in actual feeding trials the dry matter of silage has proven fully as valuable as that in roots.[119] Corn silage contains a much larger percentage of dry matter than even sugar beets, and two and one-half times as much as mangels or rutabagas. Therefore, silage is worth much more per ton as a feed than roots.

In the extreme northern districts of the United States, where corn often does not mature sufficiently for silage, roots are an economical winter succulence, for they thrive under these climatic conditions and produce large crops. Also, as is pointed out later in this chapter, roots are highly esteemed by breeders feeding cows on official tests, for with them the object is maximum production, rather than economy of production. Roots are really watery concentrates rather than roughages, for they are relatively low in fiber. Hence they may be used as a substitute for part of the concentrates usually fed dairy cows. This is an economical practice in districts where roots thrive, when grain is high in price. From extensive experiments in Denmark, Fries[120] concluded that 1 lb. of dry matter in roots is equal in feeding value to 1 lb. of Indian corn or a mixture of barley, oats, and rye. In trials during 2 years Wing and Savage of the New York (Cornell) Station[121] likewise found that 1 lb. of dry matter in mangels is equal to 1 lb. of dry matter in grain, and that mangels can successfully replace half the grain ordinarily fed in a ration of grain, mixed hay, and silage. The Cornell studies led to the conclusion that with concentrates costing $30 a ton mangels are an economical feed for dairy cows when they can be produced and stored for $4 a ton. (368) Similarly, Haecker found at the Minnesota Station[122] that 1 lb. of dry matter in mangels or rutabagas is substantially equal to 1 lb. of mixed grain, 11 lbs. of mangels or 9 lbs. of rutabagas having the same value as 1 lb. of grain.

In the earlier years it was thot that the feeding of roots produced watery milk, but the extensive experiments in Denmark and this country with roots and silage prove beyond a doubt that the milk of the cow cannot be watered by supplying succulent feeds.

639. Roots for cows on official tests.—Many breeders esteem roots highly for cows which are being forced to the utmost production on official tests. They have a "cooling" effect on the digestive organs, helping to prevent digestive trouble when cows are fed all the rich concentrates they will consume. In addition adding roots even to a palatable ration containing good corn silage seems to increase slightly the yield of milk and fat, doubtless because roots are especially well-liked by cows. This is shown in 3 experiments by Shaw and Norton at the Michigan Station[123] and a trial by Morrison and Humphrey at the Wisconsin Station.[124] Averaging together the results of the Michigan trials, it is found that when the cows were fed the excellent ration of 9.2 lbs. con-

[119]Ohio Rpt. 1893; Penn. Rpt. 1890; Vt. Rpt. 1895.
[120]Expt. Sta. Rec. 14, 1903, p. 801.
[121]N. Y. (Cornell) Bul. 268.
[122]Minn. Rpt. 1913.
[123]Mich. Bul. 240.
[124]Unpublished data.

centrates, 5.0 lbs. clover hay, and 30.8 lbs. corn silage, the average yield of milk was 22.5 lbs. a day and of fat 0.88 lb. When there was added to this ration 18.3 lbs. of roots per head daily, the daily yield of milk was increased 1.3 lbs. and of fat 0.05 lb. An increase of this sort is important for the breeder seeking high records of production. However, this practice is rarely economical for dairymen in general, for in these trials the increase in production was not great enough to offset the cost of the roots added to the ration, taking the market price for the milk.

640. Potatoes.—A heavy allowance of potatoes produces milk of poor flavor. They may be used with success, however, when not over about 33 lbs. of cooked potatoes are fed per head daily, or somewhat less of the raw tubers. When feeding a heavy allowance of potatoes, Hills of the Vermont Station[125] found the dry matter in corn silage superior to that in raw potatoes. Butter from the potato-fed cows was salvy. (374)

641. Osage oranges.—Hooper of the Kentucky Station[126] reports that he has fed daily to dairy cows 10 to 13 osage oranges, each weighing about 1 lb. on the average. The oranges were gathered in the fall before being frozen and were buried in a mound of earth, where they kept satisfactorily thruout the winter. Some cows refused to eat the osage oranges, because of the somewhat bitter taste, while others liked them or soon became accustomed to them.

642. Wet beet pulp.—Wet beet pulp is liked by cows and produces milk of good quality when not fed in excess. In a trial by Wing and Anderson at the New York (Cornell) Station,[127] good results were secured when cows were fed 50 to 100 lbs. of wet beet pulp per head daily with 8 lbs. of grain and 6 to 12 lbs. of hay. As it has but 9 to 10 per ct. dry matter, wet beet pulp is worth about one-third as much as corn silage per ton. Beet pulp may have a higher value than given above when no other succulent food is supplied. The fermented pulp appears to be more palatable and satisfactory, tho even fresh pulp seems to stimulate the consumption of dry roughage. There are occasional reports of beet pulp tainting the milk. Buffum and Griffith of the Colorado Station[128] found 2 lbs. of fresh beet pulp equal to 1 lb. of sugar beets for dairy cows. (275)

When cows are fed little else than wet beet pulp, weak calves may result, doubtless due to the fact that the pulp is low in lime. They should therefore always have plenty of legume hay in addition, the allowance of pulp being reduced, if necessary to get them to eat the other feed.

643. Soilage.—Corn silage furnishes just as satisfactory and much cheaper feed to supplement short summer pasture than does a succession of soiling crops, such as red clover, peas and oats, sweet corn, and field corn. Where too few cows are kept to consume the silage fast enough to prevent its spoiling, or where silage is not available for any other reason, the wise dairyman will provide a well-planned succession

[125]Vt. Rpt. 1896.

[126]Information to the authors.

[127]N. Y. (Cornell) Bul. 183.

[128]Colo. Bul. 73.

of soiling crops to keep up the milk flow when pastures are scanty, for he knows that it is well-nigh impossible to bring the milk flow back to the former amount when once it has been checked by insufficient feed.

During 3 summers Woll, Humphrey, and Oosterhuis at the Wisconsin Station[129] fed 1 lot of cows which had access to limited pasture a succession of soiling crops in addition to a small allowance of mixed concentrates. Another lot received corn silage instead of soilage. In 2 of the trials each lot was given a small allowance of hay. The cows which received soilage were fed on the average 28.1 lbs. soilage, consisting of red clover, peas and oats, sweet corn, field corn, or "succotash" (mixed peas, oats and corn). The other lot received 27.3 lbs. silage a head daily. The production was substantially the same under the two systems of feeding, and the silage was decidedly more economical, due to the large amount of labor required daily to cut by hand and haul the soiling crops. This required from 1 to 2 hours a day for man and horse. Moreover, in order to have the soiling crops best utilized, it was necessary to run the feed thru a silage cutter. Silage was relished better by the cows than the succession of soiling crops.

In trials during two years by Frandsen and colleagues at the Nebraska Station,[130] when cows were fed soiling crops thruout the season, there were required on the average to grow and feed the soiling crops, 1.81 hours of labor for each 100 lbs. of milk produced. When corn silage and alfalfa hay were fed instead of the soiling crops, only 1.24 hours of labor were required per 100 lbs. of milk in raising the crops, harvesting them, and feeding them. In these trials a considerably larger acreage was required per cow to provide the feed when the soiling crops were fed than when corn silage and alfalfa hay were used instead.

In trials during 2 summers by McCandlish at the Iowa Station[131] cows fed 37 lbs. of soiling crops per head daily, in addition to limited pasture and a concentrate mixture, produced no more milk or fat than others fed 22 lbs. corn silage daily in place of the soiling crops. The higher value of silage, pound for pound, is due to the fact that it contains a much higher percentage of dry matter than most soiling crops. It is evident from these trials that dairymen have good grounds for preferring silage to soilage as a supplement to pasture.

644. Pasture.—Luxuriant pasture furnishes unexcelled feed for dairy cows, for not only is the supply of nutrients liberal, but also the feed is succulent and palatable, and good pasturage is rich in protein, mineral matter, and vitamines. (**147-50, 310**) Therefore, as is pointed out in Chapter XXIII, success in feeding dairy cattle largely consists in imitating during the rest of the year, June pasture conditions.

Thruout the northern states, bluegrass is the most common pasture for dairy cattle. This furnishes excellent grazing in spring, early summer, and autumn, but in midsummer it usually furnishes scanty feed. (**311**)

[129]Wis. Bul. 235.

[130]Jour. Dairy Science, 4, 1921, pp. 124-157.

[131]Information to the authors.

Therefore for the best permanent pasture a mixture of grasses and clovers should be seeded. (326) Red clover makes excellent pasture for dairy cows, tho care must be taken to avoid bloat. (348) With alfalfa there is much more danger of bloat, except in a few districts. (340) The carrying capacity of pastures of course varies widely, depending on the soil and climatic factors and especially on how wisely the pasture has been handled. (327) If no soiling crops or summer silage are provided for periods of drought, 1.5 to 2.5 acres of pasture should be provided per cow, but if such additional feed is furnished, the pasture allowance can be reduced to 1 acre per cow or even less. Tho dairy cows have been maintained for several years without much pasture, or even with none at all, this practice is usually uneconomical and, moreover, does not promote the health of the animals.

Many farmers make the mistake of turning their cattle on pasture too early in the spring, before the forage is well started. This not only reduces the yield of forage for the rest of the season, but is apt to cause a fall in the milk yield of the cows, for such pasturage in earliest spring is so watery that they cannot consume enough of the diluted feed to maintain their production. The use of grain and soiling crops to supplement pasture is discussed in Chapter XXIV. (659-60)

CHAPTER XXIII

FEED AND CARE OF THE DAIRY COW

I. Feeding for Milk Production

Every dairyman knows that it is in late spring or early summer while on luxuriant pasture, that the dairy herd normally reaches the maximum production for the year. To secure the largest yield during the other months the summer conditions which bring about this high production should be imitated as closely as possible.[1] These early summer conditions are: (1) a balanced ration; (2) an abundance of feed; (3) succulent feed; (4) palatable feed; (5) a moderate temperature; (6) comfortable surroundings; and (7) reasonable exercise. Upon the ability of the dairyman to maintain these favorable conditions for his herd thruout the year, depend in large measure his profits.

645. Feed a well-balanced ration.—It has been pointed out in previous chapters that cows in milk need liberal amounts of protein and mineral matter, especially lime, and furthermore that they require rations high in net energy. (**147-50, 570-4**) Therefore, it is folly to expect a large yield of milk or economical production if an unbalanced ration is fed, such as corn or other grain with only such carbonaceous roughages as timothy hay and corn silage. When a ration of this character is supplied, much good feed is wasted thru a failure to appreciate basic facts in animal feeding. (**575, 623**) Yet many farmers still fail to realize that the small amount of time and energy spent in figuring out an economical balanced ration for their herd will give the largest returns of any investment they can make. The method of computing balanced rations which are the most economical for one's local conditions is fully explained in Chapter VIII and is discussed further in this chapter. (**191-6, 650-1**) In any case of doubt as to what feeds to use any farmer will find his agricultural college and experiment station or his county agent ready to advise him.

646. Feed good cows liberally.—A good dairy cow in full flow of milk is expending fully as much energy as a horse at hard work, and hence can not be expected to get all her nourishment from roughages, even if of good quality. How much concentrates to feed is a question of great economic importance to dairymen, for in many cases roughages are the cheap and concentrates the costly part of the ration. The amount of concentrates advisable depends first on the quantity and quality of the roughages furnished; second, on the productive capacity of the cows; and third, on the relative prices of concentrates and roughages. When

[1]Eckles, Dairy Cattle and Milk Production, p. 257.

corn and other concentrates furnish total digestible nutrients nearly as cheaply as do hay and other roughages, it will be most economical to feed enough concentrates to meet the recommendations of the Morrison, Savage, or Haecker feeding standards, as has been pointed out in earlier chapters. (193, 198, 558, 572) When concentrates are unusually high in price compared with roughages, as is commonly the condition in certain sections of the West or as was the case during the World War even in the corn-belt, then it will be more economical to feed slightly less concentrates than called for by the feeding standards. (612) For the most economical production and the largest profit, cows of good dairy temperament should generally receive at least 6 to 9 lbs. of concentrates, in addition to all the good roughage, such as legume hay and corn silage, that they will consume. High producers can use more concentrates with profit. The dairyman who persists in giving his cows only such low-grade roughages as timothy hay, corn stover, etc., must pay the penalty by feeding even animals of medium productive capacity 10 to 12 lbs. of expensive concentrates daily to secure a reasonable flow of milk.

647. Cows should be fed individually.—Even when fed liberally, cows of marked dairy temperament rarely lay on flesh when in full flow of milk, provided their ration is well balanced. But cows of ordinary capacity may easily be over-fed, in which case they lay on fat instead of increasing their milk production. Since even in well-bred and well-selected herds the different cows vary widely in productive ability, to secure the most profit they must be fed as individuals, instead of giving both high and low producers the same ration. (558)

It is not necessary, however, to compute a balanced ration for each animal. All that is needed is to determine what amounts and proportions of roughages and concentrates should be used to make the most economical ration that meets the requirements for the average cows in the herd, in the manner shown in Chapters VII and VIII. In feeding the herd, each cow should then be given all the roughage she will eat, which will usually be the equivalent of about 2 lbs. of dry roughage daily per 100 lbs. live weight or of 1 lb. of dry roughage and 3 lbs. of silage. Then the amount of concentrates for each cow may be determined from one of the following rules:

1. Feed 1 lb. of concentrates per day for each pound of butter fat the cow produces a week, or
2. Feed 1 lb. of concentrates per day for each 3 to 4 lbs. of milk, depending on its richness, or
3. Feed as much as the cow will pay for at the ruling prices for feeds and products, increasing the allowance gradually until she fails to respond by an increase in production which will cover the increase in cost.

The first two rules apply only when the cows are fed abundant roughage of good quality, such as legume hay and corn or sorghum silage. Also, to fully meet their requirements and secure maximum production, cows producing 1 lb. of butter fat a day or over will require somewhat more concentrates than indicated by these thumb rules, the additional amount

IMITATE SUMMER CONDITIONS THE YEAR ROUND

The most successful dairymen imitate summer conditions as closely as possible during the rest of the year.

FEEDING ALFALFA HAY TO COWS ON PASTURE

When the pasture is short, it is essential that other feed be provided to keep up the milk flow. This may be soilage, silage, or legume hay.

CASEY JONES PRODUCED THREE TUBS OF BUTTER A YEAR

Casey Jones was a good-looking, pure-bred Holstein, but she produced only 3 tubs of butter a year. The cow tester discovered her. (From Wisconsin Station.)

"HANDSOME IS AS HANDSOME DOES"

Vickery Vale Beechwood, another pure-bred Holstein, did not look much better than Casey Jones, but she yielded 20 tubs of butter a year. (From Wisconsin Station.)

needed ranging from 0.5 to 2 lbs. for a cow yielding 1 lb. of butter fat to 4 or 5 lbs. for a cow producing 2 lbs. of butter fat a day.

Heavy producers require a narrower nutritive ratio than ordinary animals, and hence it may be advisable to alter the character of the concentrate mixture for them. It is also wise to feed a more nitrogenous concentrate allowance to cows showing a tendency to fatten, while those losing flesh should receive a larger proportion of the carbonaceous concentrates, such as the farm-grown grains. Since heifers in milk are still growing, in addition to giving milk, they should be fed more liberally than mature cows yielding the same amount of milk.

648. Succulent and palatable feed.—The great importance of succulent feed for the dairy cow has been shown in the trials which have been reviewed in the preceding chapter. (**629-44**) These show clearly that it pays to provide succulence, either corn silage or roots, for winter feeding to take the place of the green grass the cows get in summer. The value of succulent feed is due in no small measure to its beneficial laxative effect and to its palatability, which undoubtedly tends to stimulate digestion. (**109**) In general, not only should succulence be supplied, but the rest of the ration for cows yielding a good flow of milk should be as palatable as possible. Such roughages as timothy hay, straw, and corn stover may be used in limited amount, but for the best results should not constitute the chief roughage. As has been pointed out before, concentrates which are not relished when fed alone may be mixed with well-liked feed, the whole forming a palatable mixture. (**594, 608**)

The concentrate allowance should be composed of a reasonable number of feeds, for a mixture is relished better than only a single kind of grain or roughage. It is also best to feed at least 2 kinds of roughage. The most successful dairymen maintain that when a satisfactory balanced ration has been provided, it is then best to make as few changes as possible.

649. Bulkiness of concentrate mixture.—When a high producing cow is fed a liberal allowance of concentrates, there will be less tendency for her to go off feed if some bulky feeds, like wheat bran, oats, or dried beet pulp, are included in the mixture. Many experienced dairymen prefer a concentrate mixture which does not weigh more than about 1 lb. to a quart. This point is of less importance with cows of average production. With them good results can be secured from well-balanced mixtures of heavy feeds, such as ground corn, cottonseed meal, and linseed meal, provided the concentrates are spread over silage at the time of feeding.

650. Good concentrate mixtures.—When plenty of good legume hay and palatable silage is available, no further attention need be given to providing roughage for the dairy herd, for this combination cannot be improved. To select a concentrate mixture which will make a balanced ration with the roughage at hand, and at the same time be palatable,

have a good effect on the general thrift of the cows, and above all be economical, is not so easy a task. A method of working out a satisfactory ration for one's local conditions has been fully explained in Chapter VIII. As an additional guide, the concentrate mixtures in the following table are given, which will make approximately balanced rations for cows of average size and producing about 1 lb. of butter fat a day, when combined with the roughages indicated. These should be taken as suggestions, rather than as recipes to be followed exactly. Because of the limitations of space, only the feeds most commonly used thruout the United States are included in these mixtures, out of the many that are suitable for feeding dairy cows. Using these mixtures as guides, one should work out a mixture which will be most economical under his local conditions.

It will be found that these concentrate mixtures are palatable. They contain sufficient bulky feed; and when combined with the roughages stated, they should be neither too laxative nor too costive for good results. For cows on official test, dairymen will usually prefer to include a larger number of feeds in the concentrate mixture, but these mixtures contain sufficient variety for general herd feeding. For cows producing materially over 1 lb. of butter fat, the proportion of protein-rich feeds should be increased to meet the requirements as expressed in the feeding standards.

Before adopting any of these concentrate mixtures the requirements for the average cows in the herd should be computed, and the ration checked up to see whether it fully meets the requirements for this particular herd, as explained later. (**651**) It will be noted that the amounts of feed in each mixture total 1,000 lbs., and that for convenience in figuring rations, there are given the amounts of digestible crude protein and total digestible nutrients in 1 lb. of each concentrate mixture. Where the ordinary "thumb rules" for feeding roughage and concentrates are followed, which are given earlier in this chapter (**647**), no particular attention need be paid to the dry matter in computing rations for dairy cows.

Concentrate mixtures for cows producing about 1 lb. fat daily

A. To feed with 1 lb. red clover hay and 3 lbs. corn silage per 100 lbs. live weight

1. Ground corn 535 lbs.
   Linseed meal 235 lbs.
   Wheat bran 230 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.140 lb.
   Total dig. nutr., 0.782 lb.

2. Ground corn 575 lbs.
   Cottonseed meal, choice 175 lbs.
   Wheat bran 250 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.139 lb.
   Total dig nutr., 0.782 lb.

3. Ground corn 570 lbs.
Linseed meal 100 lbs.
Cottonseed meal 100 lbs.
Wheat bran 230 lbs.
In 1 lb.:
Dig. cr. protein, 0.139 lb.
Total dig. nutr., 0.785 lb.

4. Ground corn 390 lbs.
Gluten feed 380 lbs.
Wheat bran 230 lbs.
In 1 lb.:
Dig. cr. protein, 0.140 lb.
Total dig. nutr., 0.781 lb.

5. Ground oats 300 lbs.
Ground corn 300 lbs.
Linseed meal 200 lbs.
Wheat bran 200 lbs.
In 1 lb.:
Dig. cr. protein, 0.137 lb.
Total dig. nutr., 0.746 lb.

6. Ground barley 615 lbs.
Linseed meal 185 lbs.
Wheat bran 200 lbs.
In 1 lb.:
Dig. cr. protein, 0.136 lb.
Total dig. nutr., 0.754 lb.

7. Dried beet pulp 250 lbs.
Ground corn 465 lbs.
Linseed meal 185 lbs.
Cottonseed meal, choice 100 lbs.
In 1 lb.:
Dig. cr. protein, 0.139 lb.
Total dig. nutr., 0.800 lb.

8. Hominy feed 300 lbs.
Ground oats 285 lbs.
Cottonseed meal, choice 165 lbs.
Wheat bran 250 lbs.
In 1 lb.:
Dig. cr. protein, 0.139 lb.
Total dig. nutr., 0.761 lb.

B. To feed with 1 lb. alfalfa hay and 3 lbs. corn silage per 100 lbs. live weight

1. Ground corn 650 lbs.
Linseed meal 100 lbs.
Wheat bran 250 lbs.
In 1 lb.:
Dig. cr. protein, 0.110 lb.
Total dig. nutr., 0.787 lb.

2. Ground corn 650 lbs.
Cottonseed meal, choice 75 lbs.
Wheat bran 275 lbs.
In 1 lb.:
Dig. cr. protein, 0.111 lb.
Total dig. nutr., 0.783 lb.

3. Ground corn 590 lbs.
Gluten feed 160 lbs.
Wheat bran 250 lbs.
In 1 lb.:
Dig. cr. protein, 0.110 lb.
Total dig. nutr., 0.787 lb.

4. Ground oats 350 lbs.
Ground corn 400 lbs.
Cottonseed meal, choice 75 lbs.
Wheat bran 175 lbs.
In 1 lb.:
Dig. cr. protein, 0.114 lb.
Total dig. nutr., 0.754 lb.

5. Ground barley 750 lbs.
Linseed meal 70 lbs.
Wheat bran 180 lbs.
In 1 lb.:
Dig. cr. protein, 0.111 lb.
Total dig. nutr., 0.760 lb.

6. Ground kafir 750 lbs.
Cottonseed meal, choice 50 lbs.
Wheat bran 200 lbs.
In 1 lb.:
Dig. cr. protein, 0.111 lb.
Total dig. nutr., 0.760 lb.

C. To feed with 1 lb. mixed hay (1/2 red clover and 1/2 timothy) and 3 lbs. corn silage per 100 lbs. live weight, or to feed with 1/2 lb. red clover hay and 4 1/2 lbs. corn silage per 100 lbs. live weight

1. Ground corn 450 lbs.
   Linseed meal 350 lbs.
   Wheat bran 200 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.164 lb.
   Total dig. nutr., 0.780 lb.

2. Ground corn 490 lbs.
   Cottonseed meal, choice 260 lbs.
   Wheat bran 250 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.164 lb.
   Total dig. nutr., 0.776 lb.

3. Ground corn 475 lbs.
   Linseed meal 150 lbs.
   Cottonseed meal, choice 150 lbs.
   Wheat bran 225 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.165 lb.
   Total dig. nutr., 0.778 lb.

4. Ground corn 260 lbs.
   Gluten feed 390 lbs.
   Linseed meal 100 lbs.
   Wheat bran 250 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.165 lb.
   Total dig. nutr., 0.768 lb.

5. Ground oats 250 lbs.
   Ground corn 250 lbs.
   Linseed meal 330 lbs.
   Wheat bran 170 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.164 lb.
   Total dig. nutr., 0.751 lb.

6. Ground barley 480 lbs.
   Linseed meal 320 lbs.
   Wheat bran 200 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.165 lb.
   Total dig. nutr., 0.752 lb.

D. To feed with 1 lb. timothy hay and 3 lbs. corn silage per 100 lbs. live weight

1. Ground corn 380 lbs.
   Linseed meal 420 lbs.
   Wheat bran 200 lbs.
   In 1 lb.
   Dig. cr. protein, 0.180 lb.
   Total dig. nutr., 0.775 lb.

2. Ground corn 410 lbs.
   Cottonseed meal, choice 240 lbs.
   Linseed meal 100 lbs.
   Wheat bran 250 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.181 lb.
   Total dig. nutr., 0.769 lb.

3. Ground corn 225 lbs.
   Gluten feed 350 lbs.
   Linseed meal 200 lbs.
   Wheat bran 225 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.181 lb.
   Total dig. nutr., 0.768 lb.

4. Ground oats 200 lbs.
   Ground corn 200 lbs.
   Linseed meal 400 lbs.
   Wheat bran 200 lbs.
   In 1 lb.:
   Dig. cr. protein, 0.180 lb.
   Total dig. nutr., 0.746 lb.

5. Ground barley 410 lbs.
Linseed meal 390 lbs.
Wheat bran 200 lbs.
In 1 lb.:
Dig. cr. protein, 0.180 lb.
Total dig. nutr., 0.751 lb.

6. Hominy feed 175 lbs.
Ground barley 200 lbs.
Linseed meal 400 lbs.
Wheat bran 225 lbs.
In 1 lb.:
Dig. cr. protein, 0.179 lb.
Total dig. nutr., 0.755 lb.

651. Computing rations, using suggested concentrate mixtures.—To illustrate the way in which these suggested concentrate mixtures should be used in computing a ration for a given herd of cows, let us suppose that the cows in a certain farmer's herd average 900 lbs. in weight and are yielding on the average 20 lbs. of 5 per ct. milk daily. He is feeding good red clover hay and corn silage for roughage, approximately at the rate of 1 lb. of hay and 3 lbs. of silage per 100 lbs. live weight. After studying the prices of the available concentrates in the manner described in Chapter VIII, he decides that the concentrate mixture given under A-2 is the most economical for him to use; i.e., ground corn, 575 lbs.; choice cottonseed meal, 175 lbs.; and wheat bran, 250 lbs.

Let us then see if this mixture, combined with the roughage he is feeding, will make a well-balanced ration. First we must compute the requirements for a 900-lb. cow yielding daily 20 lbs. of 5 per ct. milk. Her requirements, according to the Morrison feeding standards, will be found to be 1.830 to 2.090 lbs. digestible crude protein and 14.372 to 15.172 lbs. total digestible nutrients, as shown in the following table. Then we must compute the digestible crude protein and total digestible nutrients in 9 lbs. of red clover hay and 27 lbs. of corn silage. The roughage will furnish 9.360 lbs. of total digestible nutrients, as shown in the table. Subtracting 9.360 lbs. from 15.172 lbs., the higher amount of total digestible nutrients advised in the standard, leaves 5.812 lbs. total digestible nutrients, which must be supplied in the concentrate mixture. Since 1 lb. of the concentrate mixture supplies 0.782 lb. total digestible nutrients, it will take 7.5 lbs. to meet the requirement. This will supply the nutrients shown in the table. (If concentrates were very high in price compared with roughages, it might be more economical to feed only enough concentrates to bring the total digestible nutrients to the lower figure in the standard; i.e., 14.372 lbs.)

Ration for 900-lb. cow yielding 20 lbs. of 5 per ct. milk

	Digestible crude protein Lbs.	Total digestible nutrients Lbs.	Nutritive ratio
Requirements for above cow	1.830—2.090	14.372—15.172	
Trial ration			
Red clover hay, 9.0 lbs.	0.684	4.581	
Corn silage, 27.0 lbs.	0.297	4.779	
Total in roughage	0.981	9.360	
Concentrate mixture, 7.5 lbs.	1.042	5.865	
Total	2.023	15.225	1:6.5

This ration meets the requirements in an entirely satisfactory manner. Hence, it will not be necessary to modify the concentrate mixture at all for this herd. In case the digestible crude protein in the ration had fallen too low, it would have been advisable to increase slightly the proportion of cottonseed meal or wheat bran in the concentrate mixture. On the other hand, if the protein had come above the amount advised in the standard, the proportion of these protein-rich feeds could have been correspondingly reduced.

652. Water.—Often the production of good cows is lessened merely because they can not conveniently get plenty of fresh, pure water. There is no greater folly than this, for feed and labor are expensive, while water is abundant and cheap. Of all the farm animals, dairy cows require the largest amounts of water, due to the fact that it forms 87 per ct. of the milk they yield. The amount of water they will drink depends on the yield of milk, and also on the amount of water in their feed and on the air temperature. Cows in milk require on the average about 100 lbs., or 12.5 gallons, of water a head daily, and high producing cows even more. Eckles[2] found that cows in milk drank 4 times as much water as when they were dry and farrow. In one instance a Holstein cow, producing 100 lbs. of milk a day on a ration of 18 lbs. alfalfa hay, 10 lbs. corn silage, and 14 to 20 lbs. of concentrates, drank from 216 to 307 lbs. of water daily.

When cows are fed succulent feeds, they will naturally need less water to drink than when they receive dry feeds exclusively. In trials covering 3 years Collier found at the New York (Geneva) Station[3] that cows on the average consumed in feed and drink 468 lbs. of water for each 100 lbs. of milk they yielded. Of this, about one-third was in their feed and the rest in the water they drank. In a trial by Armsby[4] a cow drank 234 lbs. of water for each 100 lbs. milk produced when fed fresh grass, and 421 lbs. for each 100 lbs. of milk when fed hay made from the same grass. At the Iowa Station[5] McCandlish and Gaessler found that cows fed soiling crops and grain in summer consumed about 350 lbs. of water in their feed for each 100 lbs. of milk produced, and in addition drank about 200 lbs., making a total of about 550 lbs. water per 100 lbs. of milk. Cows drink more water when fed a protein-rich ration than when given feeds low in protein,[6] and they require more water in warm weather than in cold weather.

There has been much discussion as to the number of times a day cows should be watered, and as to the advisability of installing automatic watering devices for providing water at all times in the stalls. High-producing animals should have water at least twice a day, and their production will usually be increased if automatic water bowls are installed in the barn so they can have a drink whenever they wish one,

[2] Dairy Cattle and Milk Production, p. 242.
[3] N. Y. (Geneva) Rpt. 11, 1893.
[4] Penn. Rpt. 1888.
[5] Jour. Dairy Science, 2, 1919, pp. 4-8.
[6] Armsby, Wis. Rpt. 1886.

just as we do. This is shown by the experience of numerous breeders, as well as the results of trials conducted by Woodward and McNulty of the United States Department of Agriculture.[7] In regions with severe winters, cows should be watered indoors when the weather is so bad that it is not desirable to turn them out for exercise.

In studies at the South Dakota Station[8] Larsen and colleagues found that the composition of the milk was unchanged when cows received only half the normal amount of water or when they were watered only once in 60 hours, but under such conditions the yield of milk was decreased and the cows became nervous and gaunt in appearance. When cows were supplied alkali water from a well in place of normal water, they excreted more urine, but their health was not injured nor the quality of their milk affected. In some instances the bad results attributed to alkali water may be due to the cows drinking foul, stagnant, alkali water from a surface pool.

653. Salt.—That dairy cows must have salt to thrive is shown clearly by the studies of Babcock and Carlyle, which have already been reviewed. (**100**) They state that cows in milk should receive at least 1 ounce of salt a day, and heavy producers still more. They conclude that 0.75 ounce daily per 1,000 lbs. live weight, with 0.3 ounce in addition for every 10 lbs. of milk, is generally sufficient. Cows may be allowed free access to salt; they may be fed salt at regular intervals; or it may be mixed with their feed. A plan followed by many dairymen is to mix 0.5 lb. to 1.0 lb. of salt with each 100 lbs. of concentrates, and then in addition to provide salt so the cows can have access to it and take all they wish.

II. Hints on Caring for Dairy Cows

654. Shelter and comfort.—In winter the steer, gorged with feed and every day adding to the heat-holding layer of fat just beneath the skin, prefers the yard or open shed to the stable. The cow of dairy type and temperament stands in strong contrast, her system being severely taxed thru the annual drain of maternity and the daily loss of milk. She is spare instead of being protected by fat and consequently has more body surface to radiate heat than the steer per 100 lbs. live weight. Furthermore, her hide is usually thinner and her coat more scanty than in the case of the beef steer. She should therefore be comfortably housed in a well-ventilated, well-lighted stable, having a temperature not below 40° to 50° F. in winter. This is no higher than can readily be secured without artificial heat, even during severe weather in the northern states, if the stable is well-built and is provided with an efficient ventilating system. (**102**)

Farther south, less shelter is needed. In the climate of central Pennsylvania, Davis[9] found that cows stabled in a rather poorly-ventilated

[7] Information to the authors.

[8] S. D. Buls. 132, 147, 175.

[9] Penn. Rpt. 1913-14, pp. 183-226.

barn produced 2 per ct. more milk from each therm of net energy in the feed they consumed, than cows sheltered in an open shed. In trials carried on at Beltsville, Maryland, during 3 years by Woodward and colleagues of the United States Department of Agriculture,[10] cows ate more feed and produced slightly more milk when allowed the freedom of an open shed than when housed in a well-ventilated barn, but the increase in production was not great enough to offset the additional feed consumed. Therefore, the production was more economical in the barn. When kept in the open shed, there was a tendency for "boss cows" to keep others from their feed. More labor was required with the cows in the open shed, partly because they had to be driven to a small barn and confined in stanchions at milking time.

To preserve the health of the herd as well as for sanitary reasons, it is advisable to have no less than 4 square feet of window glass for each animal. It is well to disinfect the stable thoroly at least once a year, to check any possible spread of disease. As the dairy cow is a sensitive, nervous animal, the wise dairyman will provide comfortable stalls or swinging stanchions, and see that the cows are well bedded. The benefits from dehorning have already been pointed out. (**566**) The sharp decline in milk production which often occurs in midsummer, charged by many to the annoyance of the cows by flies, undoubtedly is more often due to a shortage of feed and to the heat. Beach and Clark at the Connecticut (Storrs) Station[11] and Eckles at the Missouri Station[12] found no increase in milk production when the herd was sprayed with a fly repellant, tho the cows were less restless during milking when they had been previously sprayed.

655. Exercise.—In the northern states during the winter, the cows should be turned out daily for exercise for about 1 to 2 hours, except in stormy or unusually severe weather, in a sunny yard which is sheltered from the prevailing winds. Such exercise will aid in keeping them thrifty, but forcing them to stay outside a good share of the day in cold weather is a waste of feed and will commonly reduce the yield severely. In the South, winter pasture should be provided whenever possible.

656. Preparation of feed.—Since the cow giving a large flow of milk is working hard, her grain should be ground or crushed and roots should be sliced or pulped. There is no advantage in cooking or soaking ordinary feeds.

657. Frequency and order of feeding.—On account of the large capacity of the cow's paunch and the considerable time needed for chewing the cud, the common practice of feeding cows twice daily, with possibly a little roughage at noon, is a reasonable one. The particular order of feeding roughage and concentrates is not important, tho the same order should be followed from day to day and the cows should be fed at regular intervals. Many dairymen feed the concentrates before

[10] U. S. D. A. Bul. 736. [11] Conn. (Storrs) Bul. 32. [12] Mo. Bul. 68.

the roughages and prior to milking, as the cows then often seem more contented and eat the roughage at their leisure after they have finished the more toothsome part of the ration. Hay and other dry forages are usually not fed till after milking, because they fill the air with dust. Silage, turnips, cabbage, or other feeds with a marked odor should be given only after milking, tho when the barn is well-ventilated corn silage of good quality may often be fed before milking, along with the concentrates, without tainting the milk.

658. Regularity and kindness.—For the best results with dairy cows, as with other farm animals, they should be treated with kindness at all times, and regularity in feeding and care should be observed. The highest yielding cows are usually of nervous temperament, and, especially with such animals, excitement often causes a sharp decrease in yield. Cows being driven should not be hurried and attendants should never strike or otherwise abuse them.

Good dairymen now realize the fact brought to public attention by W. D. Hoard of Wisconsin that dairying is based on the maternity of the cow, and treat their animals accordingly. As Haecker writes,[13] "If you so handle the cows that they are fond of you, you have learned one of the most important lessons that lead to profitable dairying. . . . A cow's affection for the calf prompts the desire to give it milk; if you gain her affection she will desire to give you milk."

Changes in the daily routine which do not unduly disturb cows apparently have no great effect on their yield. It is always desirable to have the same man milk each cow at every milking. However, a change will usually not affect the yield of milk markedly, if the new man is as good a milker as the former one. Grisdale of the Ottawa Experiment Farms[14] found that irregularity in the intervals between milkings slightly reduced the quantity and quality of the milk. When the changes were not sudden, the effect due to the difference in the length of the intervals between the milkings was negligible.

While milking is usually regarded as a simple task which anyone can do, there may be a great difference in the returns which different milkers get from the same cow. A cow should be milked quietly and briskly with the dry hand. The milker should be careful to milk each cow dry and get all the strippings, for the last-drawn milk may contain 10 times as much fat as that drawn first. (553) The "Hegelund" method of manipulating the cow's udder after nearly all the milk has been drawn, so as to bring down all remaining traces, was strongly advocated by some. Trials at the New York (Cornell) and the Wisconsin Stations[15] show that there is no material advantage in this method over milking by the ordinary method, provided the milker is careful to perform his task thoroly and milk the cows dry.

[13] Minn. Bul. 130.

[14] Ottawa Expt. Farms, Rpt. 1901, 1902.

[15] N. Y. (Cornell) Bul. 213; Wis. Rpt. 1902.

III. Feeding Cows in the Summer

659. Feeding the herd on pasture.—The proper feeding of milk cows on pasture is much simpler than during the winter, and doubtless this is the reason that so many farmers, busy with their crops, fail to give their herd the necessary attention in summer. Often the cows are merely turned to pasture after milking at night and in the morning, with no further thot as to the supply of feed actually available for them. It is then no wonder that when the pasturage becomes scanty in midsummer, the cows run down in flesh and fall off severely in yield of milk. Even if fed liberally when barn feeding starts in the fall, quite commonly they can not then be brought back to their usual production.

Many also make the mistake of turning the herd to pasture before the grass is well started. This not only injures the pasture but also is apt to decrease the yield of milk, for such early herbage is watery and contains little nourishment. It is best to wait a few days and also to continue giving the cows some hay or silage in the barn after they are turned to pasture, until there is plenty of good grazing. At all times cows at pasture should be provided with fresh water and shade, and in fly time they had best be protected from flies by spraying with a fly repellant.

If there is ample pasture, no grain or other additional feed need be fed to any except very high-producing cows when pastures are at their prime in late May and June. However, it is usually advisable to feed cows producing 1 lb. of fat a day or more some concentrates, unless the grazing is unusually luxuriant. The amount to be fed must be left to the business judgment of the individual dairyman. Later on in July and August, in districts where pastures become parched and scanty at this season, it is essential to provide plenty of feed for all the cows in milk, if a profitable yield is to be maintained. If this is not done the cows will not only drop in flow of milk, but will also run down in flesh so that they will not be in condition to give a good yield the following winter. Even when the feeding of concentrates does not apparently give an immediate profit, it may yet be highly advisable on account of the after-effect on the cows, as well as the increased value of the manure returned to the pasture when the cattle are fed concentrates. (437-8) In a trial by Roberts of the New York (Cornell) Station[16] a lot of cows fed 4 lbs. of concentrates per head daily on pasture produced 28 per ct. more milk that summer than a lot of cows of similar productive capacity which received no concentrates in addition to pasture. Also, presumably due to their better condition, because of the feeding of concentrates the previous summer, they gave more milk the following summer, when neither lot had concentrates when on pasture.

[16] N. Y. (Cornell) Buls. 36, 49.

Since immature pasture crops are much richer in protein than hay cut at the usual stage of maturity (**81, 310**), the concentrate mixture for feeding on pasture need contain only half to two-thirds as large a proportion of protein-rich feeds as is needed for winter feeding.

660. Summer silage and soiling crops.—When pastures become parched in midsummer, it is much more economical to rely largely on summer silage or soiling crops to supplement them than to try and keep up the production by feeding only concentrates. It has been pointed out in the previous chapter that when sufficient cows are fed to use up the silage fast enough to keep it from spoiling, silage is usually a much more economical feed than soiling crops. (**643**) If soiling crops are used, it should be borne in mind that as a rule they are more watery than good corn silage, and hence it is necessary to feed 40 to 50 lbs. or more to supply as much dry matter as in 10 lbs. of hay.

IV. Feed and Care Before and After Calving

661. Cows need a rest.—Dairymen agree that it is most profitable to give the dairy cow a rest between lactation periods, by drying her off at least 6 weeks before freshening, for she will then produce more milk annually than if milked continuously.[17] If she is in thin condition, she had best be allowed a rest of 8 weeks. This dry period provides an opportunity to get the cow into good shape for a hard year's work and to give her digestive tract a rest from heavy grain feeding. Dairymen differ as to the best length of lactation period, but so far as the available data warrant conclusions, there is no apparent difference in the annual returns from cows again freshening 9, 10, or 12 months after calving, providing they are allowed to be dry for 6 to 8 weeks.[18]

To avoid injury to the udder, the cow should be dried off gradually. It is well to milk only once daily for a few days, not stripping the udder out clean; then but once in 2 days for 3 or 4 days, after which the interval is lengthened to twice a week. When the milk yield is decreased to 10 lbs. per day or less, according to Eckles,[19] milking may be entirely discontinued. The udder will fill for a few days, but the milk will be gradually reabsorbed, and no harm will result. If the cow continues to produce more than 10 lbs. a day, her concentrate allowance should be withheld and only poor roughage, like timothy hay, fed until the flow is checked.

662. Feed for the cows when dry.—To ensure a good flow of milk the following lactation period and also to lessen trouble at calving, the cow should be thrifty and in fairly good flesh at freshening. (**557**) If she is dry during the pasture season and there is plenty of pastur-

[17] Carroll, Utah Bul. 127.

[18] Carroll, Utah Bul. 127.

[19] Dairy Cattle and Milk Production, p. 230.

age, no additional feed need be supplied, but if pastures become short, she should be fed enough additional feed, especially silage or soiling crops, to put her in good condition before calving. In winter, except in the case of a test cow (674), only sufficient concentrates should be fed to put her in proper flesh. No better ration can be provided than silage and legume hay with 2 to 4 lbs. of concentrates, depending on the condition of the cow. Just previous to calving time, the feed should be slightly laxative, tho if on pasture, no especial attention need be given to this point. The cow soon to calve should have exercise, but must not be chased by dogs or driven thru narrow gates.

663. Gestation period; calving time.—The average gestation period of the cow is placed by various authorities at from 280 to 285 days. Wing of the New York (Cornell) Station[20] found the average of 182 recorded gestation periods for the cow to be 280 days, ranging from 264 to 296 days. About an equal number of births occurred on each day from the 274th to the 287th, inclusive. The gestation period was not different for the sexes.

Unless the herd is at pasture, the cow should be kept in a clean, comfortable, well-bedded box stall at calving time. If her bowels are not moving freely, give a drench of Epsom salts. As parturition approaches, the udder will become distended and hard, and when the muscles on each side of the tail head relax, leaving a hollow on each side, the calf may be expected within 24 hours, or 3 to 4 days at the longest. If a considerable amount of concentrates have been fed while the cow was dry to get her into good condition, the allowance should be reduced a few days before calving, and laxative feeds used, such as a mixture of 2 parts bran and 1 part linseed meal. If this does not have the desired effect, a dose of 1 quart of linseed oil or 1 lb. of Epsom salts should be given.[21] Freedom from milk fever and other troubles after calving is largely due to the feed and care the cow receives just previous to freshening.

The cow should not be molested during calving, unless assistance is required. For 2 or 3 days after calving, her drinking water should be lukewarm, and she should be protected from cold drafts, for her vitality is then low. If necessary, the afterbirth should be removed by a thoroly competent person, and the cow should never be allowed to eat it. Many experienced dairymen advise separating the calf from the cow within 24 hours after birth, as the cow usually does not then miss the calf and fret for it, as she would had it been left with her for 2 or 3 days.

The feed for the first few days after calving should be very limited in amount and cooling and laxative in nature. The first day or two only legume hay and a limited amount of silage should be fed, with bran mashes. Then such a mixture as bran, oats, and linseed meal may be substituted for the bran. High-producing cows should be

[20] N. Y. (Cornell) Bul. 162.

[21] McCandlish, Iowa Cir. 34.

watched closely for signs of milk-fever, and the air treatment, the great boon to dairymen, used if necessary.

The yearly production of the cow depends in a large measure on the feed she receives during the first month after calving. It is even more essential to increase the concentrate allowance of the dairy cow gradually after calving, than it is to use care in getting the fattening steer on full feed, for her system has been weakened by parturition. Starting with 4 or 5 lbs. of concentrates on the fourth or fifth day after calving, the allowance should be increased gradually, at the rate of a half-pound every other day until she is on full feed, for heavy feeding immediately after calving is apt to lead to digestive disturbances. If the udder is swollen and hard, even more care should be used in getting the cows to the full ration.

It is quite customary to save the seventh milking after the cow calves for human use, altho sometimes the milk is not normal before the eighth or ninth milking. A simple test for normal milk, is to heat a small quantity to boiling; if the sample does not thicken, due to the high content of albumin, the milk is usable. (115)

664. Fall vs. spring freshening.—Spring-fresh cows yield most of their milk when low prices prevail for dairy products and the dairyman is busiest with the crops. In winter such cows yield only a small flow at most. On the other hand, the fall-fresh cow gives a large supply of milk during the winter, and flushes again with the stimulus of pasture in springtime. Fall-fresh cows should annually yield from 10 to 20 per ct. more milk than those calving in the spring. When cows freshen in the fall, more of the work of milking comes in the winter when farm work is slack. More time can be given to the raising of the calves, and less trouble will be experienced from scours than during the summer. Fall-dropped calves are large enough by spring to make good use of pasture and better able to stand the hot weather. Under this system, moreover, a larger supply of skim milk is available for the pigs in winter when there is especial need of this valuable feed.

CHAPTER XXIV

COST OF MILK PRODUCTION—BREED COMPARISONS—FEEDING TEST COWS

I. The Cost of Milk Production

During the past few years the interest of dairymen in the cost of milk production has been intense and widespread. This is largely because the costs of feed and labor and the other expenses in producing milk increased more rapidly in many sections of the country during the World War than did the prices for dairy products. As a result there arose a general demand by farmers for accurate information on the cost of producing milk under average farm conditions. This was needed not only as a basis for convincing consumers of the necessity of prices more remunerative to the producer, but also as a guide to more economical methods of production. To secure definite data on this important matter, scores of investigations have now been carried on by the various experiment stations and the United States Department of Agriculture. These investigations have not only furnished much accurate information on the cost of producing milk, but have also pointed out ways in which the individual farmer can reduce his own cost of production, so that in many cases he can secure a satisfactory profit where otherwise there might be a loss.

665. Factors in cost of milk production.—The cost of milk production is made up of the following factors:

1. The cost of feed and bedding is by far the largest single item in the cost of producing milk, making up from one-half to two-thirds the total gross cost. This expense will of course vary widely, depending on the price of the various feeds, the productive capacity of the herd, and the economy of the rations used.

2. The cost of man and horse labor is next in importance. This includes the labor of milking, feeding and caring for the cows, cleaning the stables, handling and hauling milk, and all miscellaneous work connected with the herd. The labor cost will make up at least one-fifth to one-fourth the total gross cost.

3. The building charge includes interest, taxes, and depreciation on the proportion of the barn actually occupied by the cows and the feed storage for the dairy herd. Repairs should also be included under this item or under "miscellaneous."

4. The equipment charge covers interest, insurance, depreciation, and any taxes on milk utensils or machinery, tools, etc.

5. The cow charge, which covers depreciation, interest, taxes, and

mortality risk on the cows themselves, is a larger item than often believed. First of all, the average useful life of dairy cows in the herd after they first freshen is estimated by various authorities at only 5 to 7 years. While many cows have a much longer period of usefulness, on the average the cows will be replaced within this period, due to injury or contraction of disease, failure to breed, or low milk yield. The annual depreciation is computed by finding the probable difference between the cost or value of the cow when she first freshens or is purchased and the price she will bring for beef when she is discarded. For example, if a cow is worth $125 when she first freshens, then has a useful life of 6 years, and finally brings $60 when sold for beef, the annual depreciation will be one-sixth of $65, or $10.83. The taxes paid on the cows, interest on their average valuation, and the mortality risk must also be included in the charges. With dairy cows the annual mortality risk is usually about 1.5 per ct., when the health of the herd is properly safeguarded.

6. The cost of keeping the sire must be pro-rated among the cows, or the cost of bull service must be included in herds where a bull is not owned.

7. Under "miscellaneous" are included such items as cash paid for hauling milk, cost of consumable supplies, veterinary services, cow-testing association dues and other miscellaneous items. Some of these expenses are sometimes carried under the "cow charge."

In computing the labor cost, commonly all the man labor, both of hired laborers and of the owner and manager, is figured at the current rate for ordinary farm labor. Then an item is often added to cover managerial ability and business risks, a common estimate for this being 10 per ct. of the other total costs.

666. Credits in determining cost of production.—From the total gross cost of maintaining dairy cows, which will include the various items just enumerated, must be deducted the value of the manure secured and the value of the calves at a few days of age. Commonly, the value of the manure produced on pasture is not deducted directly, but the pasture charge is based upon the fact that the fields will be improved by the manure voided on them. The value of the calves will of course vary widely, depending on the breeding of the cows and the sire. In studies of the cost of milk production where some herds include pure-bred cows, these are commonly valued at the price of high grades of similar productive capacity, and the calves credited at usual veal or grade prices. This is done so as to differentiate between the financial returns from the two enterprises—the breeding of pure-bred stock and the producing of milk.

667. Annual cost of keeping cows.—From the large amount of data which has been secured in recent years on the cost of milk production, the following summaries of investigations carried on in 6 states are presented. The expenses of producing milk are now much lower than when most of these studies were made. Since costs are constantly

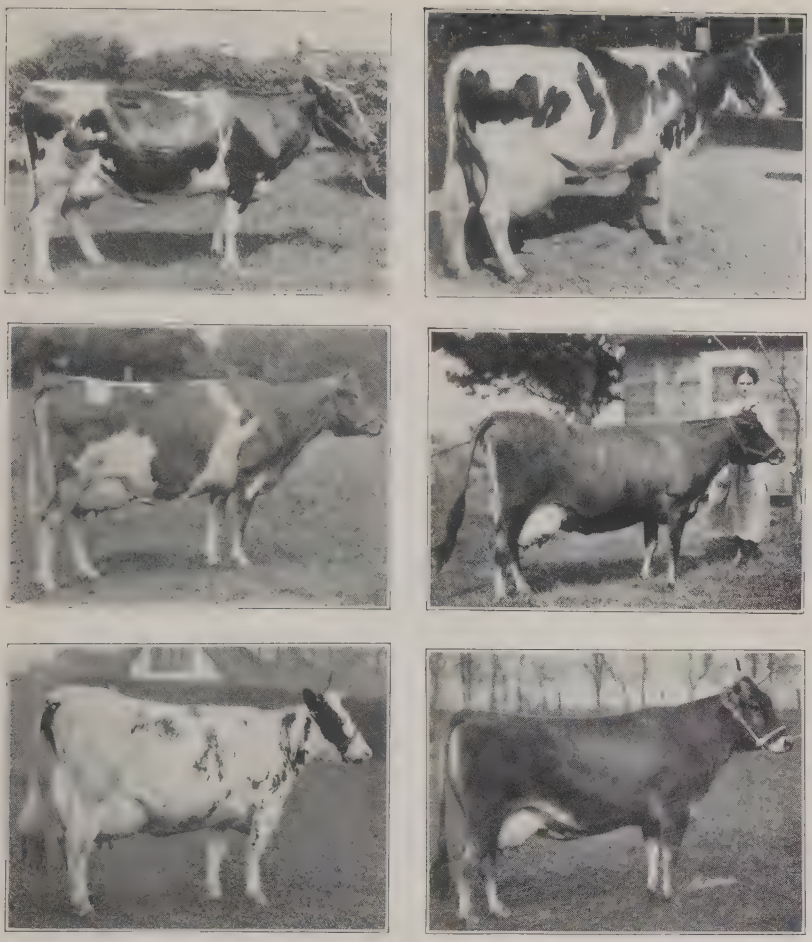
changing, the financial figures must be regarded as examples, rather than as averages for any particular district. From the amounts of feed consumed and labor required annually, one can readily compute the cost of these major items under his own conditions. The other costs do not vary as widely from year to year, and further, make up only one-fourth or less of the total gross cost. Where no figures are given for certain items, they were not reported, or the costs are included under other expenses.

Annual cost of keeping dairy cows

	Vermont[1] 1916-18	Ohio[2] 1918	Wisconsin[3] 1920-21	Minnesota[4] 1918	Iowa[5] 1916-17	Nebraska[6] 1917-20
No. of cows	847	1,124	394	1,304	900	495
Av. milk yield, lbs	5,252	5,884	7,115	5,114	4,564	5,823
Feed consumed						
Concentrates, lbs	1,030	1,534	1,555	1,014	1,785	1,529
Hay, lbs.	3,512	1,462	2,867	2,488	3,074	3,256
Other dry roughage, lbs.	88	1,064		1,686	1,309	1,019
Succulent feeds, lbs	5,307	5,455	8,430	2,550	5,342	3,593
Pasture, days or acres	3.0	187	168	2.0	2.0	...
Bedding, lbs	263	770	883	2,000	1,213	340
Labor						
Man, hrs	123	163	149	146	147	114
Horse, hrs.	24	27	..	30	57	3
Costs						
Feed and bedding	$ 57.99	$105.60	$116.60	$ 77.21	$ 97.79	....
Labor	22.10	44.72	56.00	37.21	35.10	.....
Building charge	8.00	8.10	....	3.64	8.66	$ 11.01
Equipment charge	4.39	3.00	....	.81	3.12	5.65
Cow charge	11.06	9.80	.....	13.23	7.70	14.54
Bull charge	2.01	2.50	....	4.00	4.34	8.19
Miscellaneous	....	4.30	48.14	1.08	3.30	11.74
Total gross cost	$105.55	$178.02	$220.74	$137.18	$160.03	.....
Credits						
Manure	$ 13.25	$ 17.17	$ 24.38	$ 20.00	$ 9.02	$ 9.68
Calves	5.84	7.56	8.15	5.00	7.35	12.94
Total credits	$ 19.09	$ 24.73	$ 32.53	$ 25.00	$ 16.37	.....
Net cost	$ 86.46	$153.29	$188.21	$112.18	$143.66	.....
Average yearly cost of 100 lbs. milk	$ 1.65	$ 2.61	$ 2.65	$ 2.19	$ 3.15	....

[1]U. S. D. A. Bul. 923, Bain, Posson, and Hotis.
[2]Ohio Bul. 334, Grady and Bugby.
[3]Wis. Bul. 345, McNall and Mitchell.
[4]Minn. Bul. 173, Peck and Boss.
[5]Iowa Bul. 197, Munger.
[6]U. S. D. A. Bul. 972, Bain, Braun, and Gannon.

It will be noted at once that the average production of milk in these herds was over 6,000 lbs. a year in only one instance, and this investigation was carried on with members of a cow-testing association, whose cows were undoubtedly better producers than the average of the district. The estimated expenses for the various items vary quite widely, depending not only on local conditions, but also on the methods of accounting and



CHAMPION COWS OF THE DAIRY BREEDS, 1922

Upper, left.—Holstein cow, Bella Pontiac. Record at 5 years of age, 27,191.0 lbs. milk, containing 1,270.0 lbs. butter fat. (World's record for butter fat production.) Owned by T. A. Barron, Brantford, Ontario, Canada. (Photo from *Hoard's Dairyman.*)

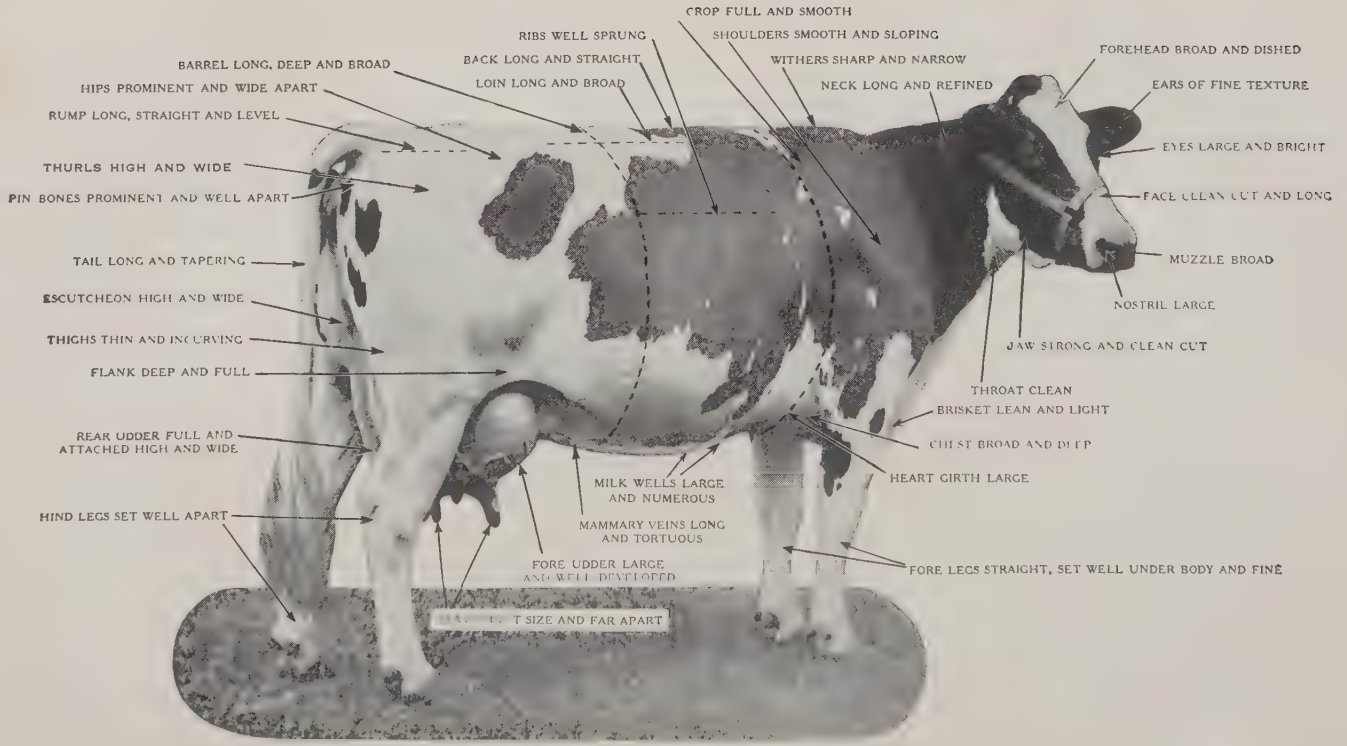
Upper, right.—Holstein cow, Segis Pietertje Prospect. Record at 6 years of age, 37,381.4 lbs. milk, containing 1,158.95 lbs. butter fat. (World's record for milk production.) Owned by Carnation Stock Farms, Seattle, Wash.

Middle, left.—Guernsey cow, Countess Prue. Record at 7 years of age, 18,626.9 lbs. milk, containing 1,103.28 lbs. butter fat. Owned by F. L. Howes, Groton, Mass.

Middle, right.—Jersey cow, Lad's Iota. Record at 5 years of age, 18,630 lbs. milk, containing 1,048.07 lbs. butter fat. Owned by J. S. McKee, Independence, Oregon. (Photo from *Jersey Bulletin.*)

Lower, left.—Ayshire cow, Lily of Willowmoor. Record, 22,596.0 lbs. milk, containing 955.56 lbs. butter fat. Owned by Gossard Breeding Estates, Martinsville, Ind.

Lower, right.—Brown Swiss cow, Hawthorne Dairy Maid. Record at 5 years of age, 22,622.6 lbs. milk, containing 927.23 lbs. butter fat. Owned by Hawthorne Farm, Libertyville, Illinois.


CROP FULL AND SMOOTH
RIBS WELL SPRUNG
SHOULDERS SMOOTH AND SLOPING
BACK LONG AND STRAIGHT
WITHERS SHARP AND NARROW
BARREL LONG, DEEP AND BROAD
LOIN LONG AND BROAD
NECK LONG AND REFINED
FOREHEAD BROAD AND DISHED
HIPS PROMINENT AND WIDE APART
EARS OF FINE TEXTURE
RUMP LONG, STRAIGHT AND LEVEL
EYES LARGE AND BRIGHT
THURLS HIGH AND WIDE
FACE CLEAN CUT AND LONG
PIN BONES PROMINENT AND WELL APART
MUZZLE BROAD
TAIL LONG AND TAPERING
NOSTRIL LARGE
ESCUTCHEON HIGH AND WIDE
JAW STRONG AND CLEAN CUT
THIGHS THIN AND INCURVING
THROAT CLEAN
FLANK DEEP AND FULL
BRISKET LEAN AND LIGHT
REAR UDDER FULL AND ATTACHED HIGH AND WIDE
CHEST BROAD AND DEEP
HEART GIRTH LARGE
MILK WELLS LARGE AND NUMEROUS
HIND LEGS SET WELL APART
MAMMARY VEINS LONG AND TORTUOUS
FORE UDDER LARGE AND WELL DEVELOPED
FORE LEGS STRAIGHT, SET WELL UNDER BODY AND FINE
T SIZE AND FAR APART

The Parts of a Dairy Cow

A dairy cow should have large capacity for feed, a dairy temperament, well developed milk organs, fine quality, perfect health, and be capable of a large production of milk and butter fat. Duchess Skylark Ormsby, a former champion cow for yearly butter fat production, record 27,761.7 pounds milk, 1,205.09 pounds butter fat, shows excellence in all parts. (From Wisconsin Station.)

the exact distribution of the expenses. In some instances the credit for manure is much lower than the actual value on most farms, when proper care is taken of this valuable by-product. (441)

668. Formulas for cost of milk production.—Since it is no easy task to convert such data as presented in the preceding table from one set of prices to the prices current at another time, various simple formulas have been worked out for estimating the cost of milk production. In these formulas all the costs are reduced to terms of feed and labor. Therefore, by taking the current prices for feeds and labor, a more or less approximate estimate of the cost of producing milk can be made readily at any time. One of the formulas most widely used is that of Pearson,[7] which is based on an investigation of the cost of producing 5,683,992 lbs. of milk on Illinois farms in the Chicago market milk zone. According to this formula, the approximate annual cost of producing 100 lbs. of milk in this district is equal to the current prices for 44 lbs. concentrates, 188 lbs. silage, 50 lbs. hay, 39 lbs. other dry roughage, and 2.42 hours of man labor. In using these items as a basis for calculating the cost of producing milk, it is assumed that as the prices of feeds and labor rise or fall the other items of expense and the credit items will fluctuate more or less in the same proportion. Tho the costs of all the factors probably never change in exact unison, they usually keep close enough together for purposes of comparison.

To illustrate the method of using this formula, let us assume that the cost of a good concentrate mixture for milk production is $30 a ton, of silage $5 a ton, of hay $15 a ton, and of other dry roughage $8 a ton. Farm labor costs about 20 cents an hour, including board. At these prices the average yearly cost of producing milk will be about $2.14 per 100 lbs., according to this formula.

In the following table the original Pearson formula and a simplified formula worked out later by him are compared with some of the other formulas which have been proposed to meet conditions in various districts.[8]

Comparison of formulas for cost of milk production

Factors in formula	Pearson (Ill.)	Modified Pearson (Ill.)	Warren (N. Y.)	Food Administration	Indiana	Michigan
Concentrates, lbs	44.00	44.00	33.80	33.50	28.9	23.50
Hay, lbs	50.00	110.00	43.30	45.30	38.1	34.90
Silage, lbs	188.00	.....	100.50	102.60	104.8	110.40
Roughage, lbs	39.00	.....	10.80	11.50	9.9	15.20
Labor, hours	2.42	3.00	3.02	2.88	2.4	2.11
Corrective factor, per ct.	0	0	25	23.7	.....	45.8

It will be noted that in some of these formulas, as in that of Warren, a "corrective factor" is given. This means that the cost of the given amounts of feed and labor must be increased by the percentage indicated

[7]Ill. Bul. 216.

[8]King, *The Price of Milk*, p. 121.

to get the approximate net cost of producing 100 lbs. of milk. For example, in the case of the Warren formula the total of these costs must be increased 25 per ct. This is to cover the other costs, besides feed and labor.

669. Monthly variation in cost of production.—Every experienced dairyman knows that it costs much more to produce milk in winter than in summer when the cows are on pasture. This is because pasture is a cheap feed and, furthermore, good pasture stimulates a high yield of milk. Also much less labor is required in producing 100 lbs. of milk when the herd is on pasture than under winter feeding conditions. In an investigation by Pearson in Illinois[9] it was found that the other expenses of producing milk were more or less constant thruout the year. When all expenses were included, the net cost of producing 100 lbs. of milk in June was about 60 per ct. of the average cost for the year, and in December about 120 per ct. of the yearly cost.

Since it costs less to produce milk in the summer, the natural tendency will be for dairymen to concentrate production in the more profitable months. Therefore to secure a steady supply of milk for city consumption, the price paid farmers must be considerably higher in winter than in summer. Pearson found that the average monthly prices paid to farmers supplying milk to Chicago from 1907 to 1916 were the following percentages of the average annual price: January, 119.0 per ct.; February, 114.3 per ct.; March, 106.5 per ct.; April, 94.2 per ct.; May, 73.2 per ct.; June, 70.6 per ct.; July, 83.7 per ct.; August, 94.2 per ct.; September, 96.7 per ct.; October, 109.2 per ct.; November, 118.3 per ct.; December, 120.3 per ct. While these percentages do not correspond exactly to the differences in the cost of production for various months, they bear a rough relationship to it.

670. Reducing the cost of milk production.—The studies of the cost of milk production have shown clearly that the factor of greatest importance in determining the cost in any herd is the actual average production. This is well shown in a survey conducted among dairymen supplying the city of Rochester, New York.[10] It was found that the cost of producing milk under war-time conditions was $4.00 or less per 100 lbs. for the herds averaging over 6,000 lbs. of milk a year, while it was $4.36 for those yielding 5,000 to 6,000 lbs., $4.88 for those producing 4,000 to 5,000 lbs., and $7.10 for the herds averaging less than 4,000 lbs. These figures show clearly that dairymen who persist in keeping inefficient cows cannot expect a profit. The general principles which must be followed in building up a profitable herd have been discussed in a previous chapter. (**541-7**)

In addition to having the right kind of cows, it is imperative, as has been emphasized before, that they be fed well-balanced and economical rations. (**191-6, 645-50**) Otherwise high feed bills may eat up all possible profits. By growing suitable crops, especially legume hay and corn or

[9]Ill. Buls. 216, 224. [10]Report of Rochester Milk Survey.

other crops for silage, the amounts of expensive purchased concentrates needed may be reduced to a minimum. A factor often overlooked is having the barn conveniently arranged in order to save time in caring for the herd. Furthermore, if dairy cows are to provide the main source of income on a farm, a sufficient number must be kept to make an economical unit. If the herd consists of only a few cows, the income will necessarily be small, labor will be employed less efficiently, and if a sire is kept, this cost per cow will be greatly increased.

II. Breed Comparison of Dairy Cows

671. Wisconsin Dairy Cow Competition.—The most extensive breed competition which has been conducted in this country is the Wisconsin Dairy Cow Competition, carried on under the supervision of the Wisconsin Station.[11] Some of the data secured in this contest, in which yearly records were secured for 395 cows, is condensed in the table:

Results of Wisconsin Dairy Cow Competition

	No. of cows	Yearly yield of milk Lbs.	Yearly yield of fat Lbs.	Value of products* Dols.	Cost of feed Dols.	Net returns over cost of feed Dols.	Value of products per 100 feed units* Dols.
Breed test							
Holstein	158	14,689	503	164.40	91.07	73.33	2.08
Guernsey	157	8,465	421	131.59	70.95	60.64	2.05
Jersey	80	7,047	363	113.00	53.88	59.12	2.05
All breeds							
Highest producers	134	.....	528.8	166.82	79.10	87.72	2.33
Medium producers	133	.....	420.6	133.75	71.08	62.67	2.04
Lowest producers	131	.....	338.9	108.12	65.95	42.17	1.77

*Butter fat, $0.28 per lb., skim milk, $0.20 per 100 lbs.

The results of this competition show plainly the fact, already emphasized, that high producers yield sufficient product to much more than pay for the larger amount of feed they eat, compared with low-producing individuals. (**541-5**)

672. Exposition breed tests.—Tests of pure-bred cows of various breeds for the production of milk and butter fat were conducted at the World's Columbian Exposition held in Chicago in 1893; at the Pan-American Exposition held in Buffalo in 1901; and at the Louisiana-Purchase Exposition held in St. Louis in 1904. In each case the test was supervised by a joint committee composed of delegates representing, on the one hand, the various breed associations interested, and on the other the Association of American Agricultural Colleges and Experiment Stations. The breed associations selected the cows and had full charge of the cows and their feed and care in all particulars. The representatives of the colleges and stations took charge of all weighings of feed as well as of milk and conducted all analyses of the milk.

[11]Wis. Res. Bul. 26; Bul. 226.

From the vast accumulation of data gathered during these tests the following table has been compiled, giving some of the more striking and helpful findings.[12]

Summary of principal tests of pure-bred dairy cows at the Columbian, Pan-American, and Louisiana-Purchase Expositions

Breed	Av. daily yield per cow			Per cent fat	Feed cost 100 lbs. milk	Feed cost 1 lb. fat	Gain in live wt.	Daily return over feed cost
	Milk	Fat	Total solids					
Columbian Exposition, Chicago, 1893: best cow in 90-day test								
	Lbs.	Lbs.	Lbs.		Cents	Cents	Lbs.	Cents
Jersey	40.4	2.0	...	4.9	70.2	14.3	81	81.3
Guernsey	39.0	1.7	...	4.4	64.6	14.8	–13	64.2
Shorthorn	40.9	1.5	...	3.7	65.5	18.0	115	58.5
Pan-American Exposition, Buffalo, 1901: average of 5 cows, 146 days								
Jersey	31.0	1.3	4.2	4.2	48.8	11.5	...	22.5
Guernsey	31.6	1.4	4.2	4.3	47.9	11.1	...	23.1
Ayrshire	37.6	1.2	4.6	3.1	40.5	12.9	...	26.4
Shorthorn	36.7	1.2	4.4	3.3	48.4	14.6	...	22.7
Holstein-Friesian	44.2	1.3	5.1	3.0	40.2	13.2	...	28.6
Polled Jersey	23.4	1.0	3.1	4.4	51.5	11.6	...	15.7
French Canadian	28.5	1.1	3.6	3.8	44.2	11.8	...	20.2
Brown Swiss	35.8	1.2	3.5	3.4	45.7	13.4	...	23.3
Red Poll	33.3	1.3	4.2	3.8	45.8	12.1	...	21.8
Dutch Belted	28.0	0.9	3.3	3.2	51.4	16.1	...	15.7
Louisiana-Purchase Exposition, St. Louis, 1904: best and poorest cow, 120 days								
Jersey								
Best cow	48.4	2.3	6.7	4.8	55.0	9.7	77	42.1
Poorest cow	38.8	1.6	5.1	4.1	65.0	13.2	85	22.3
Holstein-Friesian								
Best cow	67.5	2.4	7.5	3.5	45.0	11.0	54	38.4
Poorest cow	47.1	1.5	5.1	3.2	61.0	16.5	147	15.0
Brown Swiss								
Best cow	51.0	1.8	6.1	3.4	54.5	13.7	74	23.1
Poorest cow	38.5	1.5	5.1	3.8	69.5	15.5	147	16.5
Shorthorn								
Best cow	43.4	1.7	5.5	4.0	54.5	11.7	139	27.1
Poorest cow	21.4	0.8	2.7	3.9	107.5	23.5	234	1.6

Since widely different prices were charged for feed and allowed for products at the different expositions, the returns over cost of feed in the different tests should not be compared with one another.

III. Feeding Cows on Official Test

673. Official testing of dairy cows.—Of far-reaching importance in the rapid development of the dairy industry in this country have been the advanced registry systems established by the various dairy breed asso-

[12]Data for Columbian Exposition test from the *Jersey Bulletin*, 1893, and the *Journal of the British Dairy Farmers' Association*, 1894; for the Pan-American test, from the *Holstein-Friesian Register*, October, 1901; and for the Louisiana-Purchase Exposition, from *Dairy Cow Demonstration*, Farrington, published by *Hoard's Dairyman*.

ciations. These official records of production, which are carefully supervised by representatives of the state experiment stations or of the breed associations, have furnished breeders a reliable basis for the improvement of their herds thru the selection of animals of known high-producing capacity. In purchasing foundation pure-bred animals breeders have come more and more to rely upon advanced registry records and less upon show yard successes alone. Consequently the securing of a high official record greatly increases the value not only of the cow herself, but also of her offspring. Naturally, therefore, breeders are taking a keen interest in official testing work.

The feeding and management of cows on forced production is fully as much of an art as of a science. Starting with a cow of high productive capacity, which is always necessary, the completion of a notable record depends largely upon the intelligent feeding and painstaking care of an expert herdsman. The rations and methods employed by leading breeders differ quite widely in many details. In fact, nearly every champion cow has received a somewhat different ration from the other record-breaking cows. This indicates that there are no secret formulas or methods of management which are outstanding in their superiority over all others.

The many details of feeding and caring for cows on official test can not be considered here, but only certain general principles on which breeders are generally agreed.[13] It is hoped that these may be helpful to the beginner.

674. Fitting cows for official test.—The highest production of which a cow is capable, whether in a 7-day test or on a yearly record, can be secured only when she is carefully fitted, or fattened, before she freshens. By having a cow calve in high condition she draws heavily on the store of fat in her body during the fore part of the lactation period, as has been explained in an earlier chapter. (**557**) Therefore her yield of milk, and especially of fat, is much larger than if she had calved in only fair condition.

Cows which are to be run on official test are usually allowed a somewhat longer dry period before freshening than normal, so there may be plenty of time for the cow to become rested from the strain of her previous lactation period and to put on the desired amount of flesh. The dry period for test cows will usually range from 6 to 12 weeks, probably not averaging over 8 weeks. Often the cows are allowed to rest for 3 or 4 weeks, being fed little or no concentrates, and are then fitted for the following lactation period.

Some breeders differentiate between "soft fitting" and "hard fitting," using the former method for 7-day tests, and "hard fitting" for yearly records. "Soft fitting" means getting cows very fat with soft flesh,

[13]For further information on feeding cows on test see: Erf, *Jersey Bulletin*, 41, 1922, pp. 899-900, 955-6, 1,017, 1,054-60; Keeney, N. J. Cir. 127; Larson and Putney, *Dairy Cattle Feeding and Management;* Roberts, *Feeding and Management of Dairy Cattle for Official Production;* Savage, *Holstein-Friesian World*, Dec. 3, 1921.

which will come off quickly with proper handling after the cow freshens. By this method the percentage of fat in a 7-day Holstein test is often increased from the normal fat percentage of 3.5 to 6 or 7 per ct. or even higher. Soft fitting is not believed to be conducive to maximum yields on long time tests, however. In soft-fitting, concentrate mixtures are used which are not high in protein. For example, a common one is equal parts of ground corn or hominy feed, ground oats, wheat bran, and linseed meal. Often less linseed meal is fed than in this mixture. Ground barley may be substituted for part of the corn and oats. The cow is fed practically all of such a mixture that she will clean up, along with plenty of good legume hay and silage, and often with soaked beet pulp or roots in addition. A large Holstein cow, weighing 1,600 lbs., may take 25 lbs. or more a day of concentrates while she is being fitted.

For yearly tests cows are more commonly "hard fitted," as it is called, by feeding a concentrate mixture somewhat richer in protein than when "soft fitting" is practiced. The mixture is, however, usually lower in protein than the "test mixture" fed when the cows are on test. In "hard fitting," cows are usually fattened for a somewhat longer period than in "soft fitting." Cows thus fitted are said to store a harder fat, which does not come off as quickly as with "soft fitting." Commonly one-fourth to one-third of the concentrate mixture will be bran, and the proportions of corn and oats will be somewhat smaller, and of linseed meal or other protein-rich feeds higher, than in the "soft fitting" mixture mentioned.

A typical mixture is 200 lbs. wheat bran, 100 lbs. linseed meal, 50 lbs. gluten feed, 50 lbs. cottonseed meal, 100 lbs. ground corn or hominy feed, and 100 lbs. ground oats. Many different combinations are successfully used, and the choice should depend in large part on the feeds which are most economical under one's own conditions.

When the individual preferences of a cow for various feeds are not already known, the fitting period is the time to find out just what feeds she likes best by trying out various combinations. Then later on when she is on test, it will be possible to give heed to her likes and dislikes in making up the test mixture of concentrates.

675. Feed and care at calving.—The fitting ration is usually discontinued 10 days to 2 weeks before calving and a "cooling ration" fed instead. This usually consists of all the roughage the cow wants, including roots, if possible. In addition, 2 to 10 lbs., or even a little more in some cases, is fed of such a laxative and bulky mixture as 2 parts wheat bran, 2 parts ground oats, and 1 part linseed meal. For a day or so before calving often no concentrates are fed except 2 to 3 lbs. of bran mash a day, or the same weight of a mixture of equal parts of bran and whole oats. It is essential that her bowels be in a laxative condition, and if necessary a dose of Epsom salts should be given.

A week before calving, the cow should be put in a well-ventilated box-stall, where she will be comfortable and free from drafts. The stall

should be thoroly disinfected and well bedded. At calving time she should not be disturbed, unless it is necessary to aid her. She should, however, be observed quietly at intervals to see that all is going well. The day after calving, often no feed except perhaps a bran mash is given. In any event, the feed should be very limited in amount and laxative and cooling in nature. The water should be warmed for the first 3 or 4 days, and the cow should be blanketed before and after calving, if necessary to keep her warm. Extreme care must be taken to watch for any signs of milk fever, which is especially apt to affect test cows which calve in high condition. An apparatus for the air treatment should always be at hand. The udder should not be milked dry until the third or fourth day, or the tendency to milk fever will be increased.

676. Feeding cows on test.—In making a record, much depends on the feed and care a cow receives early in her lactation period. The second and third days after calving the cow may be fed 3 to 4 lbs. of the same mixture of concentrates used in the cooling ration before freshening, or bran mashes may be continued. Her feed should never be increased beyond this limited allowance until she has "cleaned," or the after birth has come away. If all goes well, beginning about the fourth day the concentrate mixture which is to be fed during the test may be gradually substituted for the other concentrates, the change being made at the rate of 0.5 lb. to 1 lb. a day, and the allowance of concentrates gradually increased. When the cow is on a liberal ration, the daily milk record should be watched carefully to see whether she responds to an increase in feed by an increase in milk. If there is no such response, the concentrate allowance should be decreased 0.5 lb. a day, to find whether the previous allowance was slightly greater than required for her maximum. The object should be always to feed only as much concentrates as are needed for maximum production. By crowding them on rich feeds beyond the safety point in an attempt to secure a little higher production, a large number of valuable animals have unfortunately been sacrificed. In such cases they have failed to breed afterwards, their udders have been spoiled, or their digestive systems have been injured.

After three weeks the cow will be practically on full feed, consuming 15 to 20 lbs. of concentrates a day or even more. Any further increase should be exceedingly gradual—not over 0.25 to 0.50 lb. a day. The cow must never be given more concentrates than she will clean up with a good appetite, else she may be thrown off feed.

The concentrate mixtures used by various feeders for test cows differ quite widely, but nearly all have certain general characteristics. They are usually made up of a considerable variety of palatable feeds; they include a goodly proportion of such bulky feeds as wheat bran, ground oats, dried distillers' grains, and dried beet pulp, and in addition considerable protein-rich feeds, especially linseed meal, cottonseed meal, and gluten feed. A mixture such as the following is often used: Ground oats, 100 lbs.; ground corn or hominy, 100 lbs.; linseed meal, 100 lbs.;

distillers' grains, 100 lbs.; gluten feed, 100 lbs.; wheat bran, 100 lbs.; cottonseed meal, 50 lbs. In addition soaked beet pulp may be fed and 1 to 2 lbs. of molasses a day. Some breeders successfully employ mixtures containing less protein-rich feeds than in this mixture, using a combination much like the first mixture mentioned for fitting; i.e., equal parts of ground corn or hominy feed, ground oats, wheat bran, and linseed meal. Others feed even a larger proportion of protein-rich feeds. The latter practice is safe only under expert supervision and when great care is taken to provide succulent feed in silage and soaked beet pulp or roots. "Soft-fitted" cows fed for 7-day records are usually fed rations higher in protein when on test than cows fed for yearly records.

Statements have often been made that certain feeds stimulate the production of milk and of fat to an extent not explained by the amounts of nutrients they supply. However, the results of the trials which have been carried on to study this matter disagree. In some instances a certain feed has apparently stimulated milk or fat production, and in other cases there has been no such effect. In most such trials the experimental periods have been too short to warrant definite conclusions. Up to the present, there is no very positive evidence of any continued, specific effect of a feed in stimulating fat production. Some feeds, especially cocoanut meal and ground flax seed, often cause a more or less temporary increase in the fat percentage, and hence are frequently included in test rations.

For roughage a test cow should have all the choice alfalfa or other legume hay she will eat, with a limited amount of silage, commonly 20 to 25 lbs. and rarely over 30 lbs. a day. In addition, quite commonly test cows are fed what sliced roots they will eat, or 6 to 10 lbs. of dried beet pulp, soaked before being fed. Often the beet pulp is soaked in molasses water, made by diluting a quart of molasses with 10 quarts of warm water.

Test cows are commonly fed concentrates as many times a day as they are milked. This is usually 4 times a day with Holsteins, due to the large amount of milk they yield, and 3 to 4 times with the other breeds. A high-producing cow will usually give a larger yield with 4 milkings than with 2 or 3.

In summer, cows on yearly test are often turned at night into a nearby pasture where there is good feed, but this is not commonly done with those on 7-day tests. Other breeders turn their cows out only for exercise, but feed soiling crops thruout the season. The recent discovery of the relation of green feed to the assimilation of calcium by cows, emphasizes the need of some fresh green feed, either soiling crops or pasture, especially for cows crowded to high production. (**574**)

At all times test cows should have comfortable quarters, and regular care and attention, always by the same herdsman, if possible. The stable should be kept free from flies during the summer. It must always be borne in mind that only when a test cow is thrifty, comfortable, and

contented will she respond with continued production of the maximum amount of milk of which she is capable.

677. Records of champion cows.—The following summary of the records of production and feed for champion cows of the leading dairy breeds is interesting in showing how such great cows have been fed while on test:

Bella Pontiac,[14] a 5-year-old pure-bred Holstein established a new world's record of butterfat production for all breeds by producing 1,270.0 lbs. butterfat in the year ending in June, 1921. She yielded during the year 27,191.0 lbs. milk, testing 4.66 per ct. butterfat. She was dry about 6 weeks before freshening, and after calving was started gradually on a light feed of wheat bran and linseed meal, with green alfalfa for roughage. As soon as she settled down to work, she was put on a concentrate mixture consisting of 6 parts linseed cake, 2 parts wheat bran, 2 parts crushed oats, 1 part gluten feed, and with a maximum of 12 parts cottonseed meal. Of this mixture she ate from 30 to 37 lbs. a day and also had 60 to 70 lbs. of roots, 25 lbs. silage, and all the alfalfa hay she wanted. Toward the end of the year, the supply of silage was exhausted, so the allowance of roots was increased; also she was tiring of the heavy allowance of cottonseed meal. Therefore, a concentrate mixture relatively low in protein was fed, consisting of 2 parts bran, 2 parts crushed oats, 1 part linseed cake, and 1 part cream of wheat. She was fed concentrates before each milking, 4 times a day, and one-quarter pound of salt and a handful of charcoal were added to the concentrates at each feeding.

Segis Pietertje Prospect,[15] a 6-year-old pure-bred Holstein cow, yielded 37,381.4 lbs. milk, testing 3.1 per ct. and containing 1,158.95 lbs. butterfat in the year ending December 18, 1920. This made her the champion milk producing cow of the world. She was dry a little over 2 months before freshening and during this time was fitted on a concentrate mixture of equal parts ground oats, bran, hominy feed, and linseed meal, with some salt and charcoal. She was not excessively fat at freshening time. When on test she was fed a concentrate mixture of 6 parts of ground oats, 4 of bran, 3 of corn meal, 3 of hominy feed, 3 of linseed meal, 2 of soybean meal, 1 of cottonseed meal, 1 of ground flax seed, and 1 of gluten feed, with 1 lb. of charcoal added to each 100 lbs. of concentrates. The allowance of concentrates was gradually increased from 16 lbs. to a maximum of 26 lbs. daily. In addition 3 lbs. of molasses and 3 to 6 lbs. of dried beet pulp, soaked, were fed a day. For roughage she received 20 to 30 lbs. of alfalfa hay a day, and 35 to 60 lbs. of red beets, with green rye grass, oats-and-peas, or sweet corn in addition during the summer.

Countess Prue,[16] a 7-year-old pure-bred Guernsey cow, produced 18,626.9 lbs. milk, testing 5.92 per ct. and containing 1,103.28 lbs. butter-

[14]Holstein Friesian World, 18, 1921, pp. 2744-5, 2774-6.
[15]Holstein Friesian World, 17, 1920, pp. 6223-4, 6242.
[16]Guernsey Breeders' Journal, Dec. 1, 1920.

fat in the year ending November 29, 1920. During the year she was fed 19 to 22 lbs. of a concentrate mixture made up of a large variety of concentrates and modified considerably at different periods. In addition in winter she received 15 to 20 lbs. of soaked beet pulp, 21 to 31 lbs. silage, and 15 to 21 lbs. mixed hay. In summer soiling crops were fed in place of silage, and in autumn roots were added to the ration.

Lads Iota,[17] a 5-year-old pure-bred Jersey, yielded 18,632 lbs. of milk and 1,048.07 lbs. of butterfat in the year ending April 7, 1922. This record made her the champion Jersey cow of the world. While not a large cow she has great capacity and ability to consume a large amount of feed, being fed as high as 27 lbs. of concentrates a day. Wheat bran, wheat feed ("mill run"), linseed meal, rolled oats, and corn were the concentrates fed, the proportions being changed somewhat during the test. During the summer she had clover pasture, with clover hay and about 4 lbs. daily of beet pulp in addition. After the pasture season, silage and kale were fed instead.

The world's milk record for the Ayrshire breed is held at present (June, 1922) by Garclaugh May Mischief with a yearly production of 25,329.0 lbs. milk and 894.91 lbs. fat. During her record she consumed 4,946 lbs. concentrates, 668 lbs. dried beet pulp, 11,200 lbs. corn silage, 22,300 lbs. beets, 2,780 lbs. hay, and a small amount of soiling crops. The Ayrshire record for butterfat is held by Lily of Willowmoor with a record of 22,596.0 lbs. milk and 955.56 lbs. fat.[18]

In June, 1922, Hawthorn Dairy Maid, a 6-year-old Brown Swiss, completed a yearly test in which she yielded 22,622.6 lbs. milk, containing 927.23 lbs. butter fat. This made her the champion Brown Swiss cow. During the test she was fed a mixture of oats, barley, corn, bran, and molasses, with alfalfa hay and corn silage for roughage, and dried beet pulp in addition. During part of the growing season she was turned to pasture with the rest of the herd.

[17]Jersey Bulletin, 41, 1922, pp. 843-4.
[18]Ayrshire Quarterly, July, 1916.

CHAPTER XXV

RAISING DAIRY CATTLE

I. The Skim-Milk Calf

The profitableness of dairying depends to a large degree upon carefully rearing the heifer calves from the best cows in the herd and sired by a pure-bred bull of quality. Improvement of the herd can best be made by replacing the discards with well-bred, home-reared heifers of greater productive capacity. Starting with common cows, one may by this means in a few years build up a high-producing herd. On the other hand, the dairyman who replenishes his herd by purchase must pay high prices for animals which, tho of good appearance, may not be well-bred. Careful dairymen are loath to part with their best heifers, preferring to keep them to improve their own herds. Another important reason for rearing the heifers is that under this system it is far easier to keep the herd free from such diseases as tuberculosis and contagious abortion.

Tho the value of the calf at birth depends primarily on its breeding, the feed and care it receives while young are fully as important factors in deciding its future usefulness in the herd. The general principles of calf-rearing, which are presented in this chapter, are well founded upon scientific trials and practical experience, but the raising of calves will ever remain an art, in which much depends on the skill and judgment of the feeder, who should study the individual requirements of the animals, rather than blindly follow hard and fast rules.

678. Nutrients required by calves.—Before discussing the various rations suitable for feeding calves, we should have clearly in mind their nutrient requirements. It has already been pointed out in Chapter V that young growing animals require rations which furnish ample protein and plenty of mineral matter, especially calcium and phosphorus, for the rapid development of their protein tissues and their skeletons. (**113-119**) Furthermore, the protein must be of the right kind, or quality (**118**), and their rations must supply plenty of both the fat-soluble vitamine and the water-soluble vitamine for normal growth. (**104, 120**)

All these requirements are admirably met in the milk of their dams, but the fat of milk is so valuable that but few dairy calves are now reared on whole milk when skim milk is available. Fortunately, scientific trials and practical experience alike show that with proper feeding, calves changed to skim milk when but a few weeks old usually develop into just as good cows as those fed whole milk until weaning time.

Skim milk and whey are relatively low in fat-soluble vitamine, because much of it is removed in the butterfat. The question therefore naturally

arises as to whether calves raised on skim milk or whey in place of whole milk will secure enough of this vitamine, which is essential for growth. Happily, calves begin to eat roughage when only a few days old, and green-leaved forage is in general rich in the fat-soluble vitamine. Therefore, calves fed skim milk or whey probably obtain sufficient of this vitamine, even tho the concentrates fed are low in it. This is indicated in a recent trial by Morrison, Humphrey and Hulce at the Wisconsin Station[1] in which one lot of calves was fed whey, white corn, linseed meal, and wheat middlings (all these feeds containing little or no fat-soluble vitamine), with legume hay and corn silage for roughage. Another lot was fed the same ration, except that it received yellow corn, which is quite rich in fat-soluble vitamine. Both lots made satisfactory gains, there being no appreciable difference in the rate of gain or in general thrift. The fact that the calves fed yellow corn did no better than those fed white corn shows that the latter received sufficient fat-soluble vitamine in the hay and silage. (202)

In all probability most rations fed calves furnish plenty of the water-soluble vitamine for normal development, since it is quite generally distributed in ordinary feeding stuffs. (104)

679. Protein requirements for growing cattle.—Inasmuch as protein-rich feeds are usually more expensive than those rich in carbohydrates, it is a matter of great practical importance to determine how much protein is required for normal growth, or in other words, how narrow the nutritive ratio should be. For some time it has been generally believed that the Wolff-Lehmann feeding standards prescribed more protein than needed for good growth. Therefore, thru the cooperation of the National Research Council and several experiment stations, joint investigations are being undertaken to study the effect upon the rate of growth of supplying different amounts of protein in the rations of calves. Studies of this character must extend over a considerable period of years before definite conclusions are reached. In the trials thus far reported[2] calves which were fed rations containing approximately the amounts of protein now recommended in the Morrison feeding standards (Appendix Table V) made materially more rapid gains than others which were fed 32 to 42 per ct. less protein up to 9 months of age and then 42 to 50 per ct. less protein than the amount the first lot received. The calves gained only 87.2 per ct. as rapidly on the low-protein diet as on the ration higher in protein, and stored only 56.6 per ct. as much protein in their bodies. It was found that on the low-protein rations a marked depression of digestibility occurred, due to the large amount of easily digested carbohydrates compared to the amount of protein. (84) This caused a less complete utilization of the feed.

[1]Wis. Bul. 339, p. 128.

[2]Experiments by Beals and Lindsey at the Massachusetts Station, by Holdaway, Ellett, and Harris at the Virginia Station, and by Plumb, Conklin, and Lyman at Ohio State University. Summarized by Armsby, Bul. of National Research Council No. 12, June 1921.

In trials by Eckles, Ragsdale, and Swett at the Missouri Station[3] it has been found that Holstein calves fed about 75 per ct. as much protein as advised in the Wolff-Lehmann feeding standards make normal gains, but that in some instances a more liberal supply of protein than this is needed with Jerseys. On lower amounts of protein the growth of both breeds was usually retarded.

Definite conclusions regarding the minimum amount of protein needed for normal growth in cattle cannot be made till further data are secured. However, the results to date indicate that, while the amounts of protein advised in the Wolff-Lehmann standards are somewhat higher than necessary for normal growth, no great reduction can be made without checking the gains of the animals. These facts are taken into consideration in the recommendations made in the Morrison feeding standards for growing dairy cattle and beef cattle. (Appendix Table V.)

680. Skim milk vs. whole milk.—Calves fed skim milk in place of whole milk may not be quite so fat the first few months and hence may not make quite as large gains, but they usually are just as growthy and by the time they are 18 months to 2 years old, will be as large in frame and as heavy as if they had been fed whole milk until weaning time. For example in a trial by Spitzer and Carr at the Indiana Station[4] one lot of 12 calves was fed whole milk at the rate of 10 lbs. of milk daily per 100 lbs. live weight and another lot received the same amount of skim milk, the other feeds being the same for both lots. During the first 140 days the calves fed whole milk gained 1.91 lbs. a head daily, and those fed skim milk 1.73 lbs. The calves were then turned on pasture, and after this the calves which had been fed skim milk made slightly more rapid gains than those that had been fed whole milk. At the age of 18 months the calves which had been fed skim milk averaged 594 lbs. in weight, while those which had received whole milk averaged only 582 lbs.

In a similar trial Hooper of the Kentucky Station[5] fed one lot of 6 calves whole milk in a 79-day trial, while another was changed in a few days to skim milk. Each lot received in addition 0.5 lb. per head daily of a mixture of equal parts corn meal, bran, and linseed meal, besides what hay they would eat. The skim-milk calves made slightly larger gains than those fed whole milk, and were just as thrifty.

681. Supplements to skim milk.—Skim milk differs in composition from whole milk only in having had most of the fat removed. Consequently, the proportion of protein to other nutrients is much higher in skim milk than in whole milk, which is itself a protein-rich food. While the nutritive ratio of whole milk is 1:3.9, skim milk has the very narrow nutritive ratio of 1:1.5. Accordingly, in choosing supplements to feed with an ample amount of skim milk, the need is not for additional protein, but for an abundance of energy-giving, easily digested carbohydrates or fat to replace the fat removed from the whole milk. Not

[3]Mo. Buls. 147, p. 29; 151, p. 33; 172, pp. 21-2; and 179, p. 23.
[4]Ind. Bul. 246.
[5]Ky. Bul. 171.

appreciating this fact, early investigators usually advised supplementing skim milk with nitrogenous concentrates, such as linseed meal and bran.

While various fats and oils may be used to supplement skim milk, the cereal grains, rich in carbohydrates, are cheaper and more satisfactory supplements than the oils available for calf feeding. Unless oil is fed as an emulsion with the milk it is apt to produce indigestion and scours, for young animals in general have but limited ability to digest fat. (117) At the Massachusetts Station[6] Lindsey found cod-liver oil added to skim milk unsatisfactory, the calves sometimes refusing the combination. A cheap grade of oleomargarine was heated to 110° F. and mixed with skim milk by churning. It was found that 1 ounce of oil per quart of skim milk was all that the calf could take without indigestion being produced. Cottonseed oil and corn oil to the amount of one-half ounce per quart of milk were fed without bad effect.

682. Farm grains as skim-milk supplements.—That the farm-grown grains should ordinarily be used as the chief supplement to skim milk for calf feeding is shown in trials by Curtiss at the Iowa Station.[7] Different lots of calves were fed skim milk and hay, and in addition corn alone, linseed meal alone, ground oats with the hulls sifted out, or corn meal with a little flax seed. The calves fed corn or oats made more rapid and considerably cheaper gains than those fed the protein-rich linseed meal. Curtiss concluded from these trials: "In the corn-belt states, with their surplus of corn and oats, there is no necessity for the purchase of a high-priced nitrogenous product to be used in supplementing the skim-milk ration."

Nearly all the cereal grains are well suited for calf feeding. In addition to corn and oats, barley is excellent,[8] as are also the grain sorghums. The latter are especially well suited to feed with skim milk, because they are costive in effect, and tend to overcome any tendency toward scouring.[9] Duggar[10] reports that rice meal is decidedly inferior to corn as a supplement to skim milk. Because it was impossible to get the calves to eat sufficient rice meal, one third wheat bran was added.

Instead of feeding merely corn, oats, or other grain as the concentrates to calves, many dairymen prefer to mix with the grain a small proportion of such well-liked feeds as wheat bran and linseed meal to make the ration more palatable. When only a small amount of skim milk is available for the calves, sufficient protein-rich feeds should be included in the concentrate mixture to make a well balanced ration.

In teaching calves to eat, ground grain is usually fed, but later whole corn or oats gives as good or even better results than the ground grain.[11] When the calves are 6 to 8 months old, they chew their feed less thoroly,

[6]Mass. Rpts. 1893, 1894.
[7]Iowa Bul. 35.
[8]Fain and Jarnagin, Va. Bul. 172.
[9]Cottrell, Otis, and Haney, Kan. Bul. 93. [10]Ala. Bul. 128.
[11]Otis, Kan. Bul. 126; Fain and Jarnagin, Va. Bul. 172; Kildee, Iowa Cir. 16; McCandish, Iowa Res. Bul. 51.

and grinding oats or corn may then be profitable. Such hard grains as barley, wheat, and the grain sorghums should always be ground.

683. Various concentrates with skim milk.—To determine whether any advantage resulted from including a large variety of feeds in the concentrate allowance for skim-milk calves, Otis at the Kansas Station[12] fed one lot of 10 calves equal parts of shelled corn and ground kafir, while another was fed a mixture of 10 parts shelled corn, 10 parts ground kafir, 6 parts whole oats, 6 parts bran, 2 parts linseed meal, and 0.5 part dried blood. The corn and kafir mixture produced larger gains than that supplying a greater variety of feeds. In another trial no advantage resulted from adding either ground flax seed or a proprietary calf feed to ground kafir for skim milk calves.

For calves up to 3 or 4 months of age some dairymen advocate feeding ground flax seed, either added directly to the milk or made into a jelly with boiling water and then mixed with the milk, about a tablespoonful of the flax seed being used to each quart. Others report equally good results from starting directly on farm grains.

Woll and Voorhies carried on 2 trials at the California Station[13] to find whether it was advisable to add linseed meal to a mixture of equal parts ground barley, ground oats, and middlings, or to a mixture of milo and barley. In both trials the calves fed no linseed meal made just as rapid gains as the others and were thrifty. The calves fed linseed meal appeared to have somewhat sleeker coats and more pliable skin, but the difference was not marked. Also the addition of linseed meal made the concentrate mixture more palatable. The general conclusion from these trials was that it is not necessary to make linseed meal, which is usually a high priced feed, a part of the concentrate mixture for thrifty calves that have been successfully changed over to a skim milk diet.

In another trial Woll and Voorhies found that crushed carob beans and pods were well liked by calves when fed with equal parts ground milo. Thus fed they were fully equal to ground barley, pound for pound. (264) Mixtures of 1 part of either cocoanut meal or dried beet pulp with 2 parts of rolled barley were also very satisfactory for calves fed skim milk. (260, 276)

"Blackstrap" or cane molasses, which is often a cheap feed in the South, is apt to produce scours when young calves are allowed all the molasses they will eat. However, in trials at the Louisiana Station[14] Calloway found that if calves were fed 1 to 2 ounces of molasses, along with concentrates, at the start and the amount of molasses was then increased only about 2 ounces per head daily each week, there was no trouble from scouring. At the end of 21 weeks the calves were safely fed 2 lbs. of molasses a head daily with an equal weight of concentrates. (280)

684. Dried blood.—Dried blood, or blood meal, is often used as a protein-rich feed for calves raised on milk substitutes and is also fre-

[12]Kan. Bul. 126. [13]Cal. Bul. 271. [14]La. Bul. 180.

quently fed to sickly calves. For example, Otis[15] found that sickly calves, given at first a teaspoonful and later a tablespoonful of dried blood with their allowance of skim milk, rapidly regained their health. Blood meal which has been especially prepared for calves is best. In all cases it should be carefully incorporated with the milk to prevent settling. (271)

685. Salt; other mineral matter; water.—As soon as calves begin to eat grain they should be supplied with salt, the same as in the case of older cattle. (100, 653) The best plan is to give the calves access to salt and let them take what they will.

If the calves have plenty of good legume hay and skim milk or other protein-rich feeds, they will commonly secure ample calcium and phosphorus for sturdy growth. In districts where the feeding stuffs are low in calcium or phosphorus, or when straw or other roughages deficient in these mineral nutrients are fed, then one-half ounce of bone meal or ground rock phosphate per head daily should be added to the ration. If only calcium is lacking, this may be supplied by feeding one-half ounce of finely ground limestone or chalk a head daily.

In case any calves at birth show evidence of goitre, or "big neck," this should be prevented in the future by the use of iodine, as explained in a previous chapter. (574)

The calf should be amply supplied with pure fresh water, something which is often neglected with calves fed milk. Skim-milk calves will usually drink water several times a day, sipping a little at a time, sometimes soon after their feed of milk. Calves 2 to 4 months old, fed skim milk, will consume from 10 lbs. or less of water daily up to 20 lbs. or more.

686. Self feeding calves.—Because the self-feeder is used so successfully in swine feeding (926), the question has naturally arisen whether calves can be successfully raised by self feeding them concentrates in addition to supplying milk and roughage. But few trials have as yet been carried on to study this matter, but experiments by McCandlish at the Iowa Station[16] and Hulce at the Illinois Station[17] show that if calves are allowed access, free choice, to grains, such as corn and oats, and also to linseed meal, wheat bran, and other protein-rich concentrates, they will eat much more linseed meal and wheat bran than needed to balance their ration, therefore making it unduly expensive. Also, altho they will make rapid gains, after 2 or 3 months they will eat much more concentrates than are commonly fed to calves. Not only is this usually expensive, but Hulce found that after calves thus self-fed reached the age of 4 months, some became unthrifty and even had fits, quite probably due to the large amount of rich concentrates they were eating, with only a small amount of roughage.

Experiments at the Nebraska Station[18] suggest the possibility of raising dairy calves economically and with a minimum amount of labor by self-

[15]Kan. Bul. 126. [16]Iowa Res. Bul. 51. [17]Information to the authors.
[18]Nebr. Rpt. 34, 1921, p. 29; Nevens, Jour. Dairy Science, 2, 1919, pp. 435-443.

HEIFER CALVES FROM SUCH COWS BUILD UP THE HERD

A dairyman who raises no heifer calves, but replenishes his herd by buying cows, can only with great difficulty keep up a high average of production.

THRIFTY, PROMISING HEIFERS RAISED ON SKIM MILK

With proper feeding and care, skim milk calves develop into just as good cows as those fed whole milk until weaning time. When calves have plenty of skim milk, they need little or no purchased protein-rich concentrates.

HEIFERS NEED CONCENTRATES TO MAKE GOOD GROWTH

Many heifers are permanently stunted and never develop their maximum productive capacity on account of insufficient feed or an unbalanced ration.

THE DAIRY BULL NEEDS EXERCISE

Whatever method is used, it is essential that the bull have ample exercise. Otherwise he is almost certain to develop an ugly disposition, and he may become impotent. See Page 443.

feeding a suitable mixture of concentrates and chopped or ground legume hay, the proportion of concentrates and hay being adjusted so the calves do not get so much concentrates that the feed cost is high. Milk and uncut roughage would of course be furnished in addition.

687. Starting the calf on whole milk.—The skim milk calf is usually allowed to get its milk from the dam for 2 to 4 days, as the colostrum milk, secreted immediately after calving, is not suitable for human use. (115) Some dairymen prefer not to allow the calf to draw milk from the mother, or leave it with the cow only one day, believing that the cow and calf then fret less when separated, and that the calf learns more readily to drink from the pail. In any event the calf should always get the first milk, or colostrum, which is designed by nature for cleansing the bowels and starting the digestive functions. If the cow is a heavy milker, the calf should not be allowed to gorge on milk, lest scours result. After each feeding the cow should be stripped clean. When the cow's udder is caked, leaving the calf with her will aid in reducing the inflammation.

The calf is best taught to drink milk from the pail by using the fingers. If it is allowed to go 12 to 18 hours without feeding, or until it becomes genuinely hungry, much less difficulty will be experienced in the first lesson. Some dairymen use calf feeders, claiming that the slowness with which calves suck milk from the nipple, compared with drinking from the bucket, aids digestion. Hooper found at the Kentucky Station[19] that during the first 7 to 10 weeks calves were more thrifty when fed thru the nipple. After the 70th day, however, the feeder was no more effective than bucket feeding, and by the time the calves were 6 months old there was little difference in size or vigor between the lots. Many of the calf feeding devices on the market are unsatisfactory, and all are dangerous unless extreme care is exercised in cleansing and sterilizing them.

The young calf has a small stomach and naturally takes milk frequently and in small quantities. Too large an allowance of milk produces indigestion and scours. When milk feeding begins, for the first day or two only 5 to 6 pounds should be fed daily, or somewhat more for a large lusty calf, the allowance being usually divided between 2 feedings. Some advocate feeding at least 3 times a day at first, which occasions little extra work if the cow is milked thrice daily. When the cow is milked twice a day, the bother of warming the milk at noon is held by many not to be repaid. In all cases the milk should be fed as fresh as possible and at blood heat, or about 100° F. The temperature should be determined by a thermometer, instead of guessing at it. The allowance of milk should be gradually increased, but over-feeding, the common cause of poor success in calf rearing, should be avoided at all times. A safe rule is always to keep the calf a little hungry. Calves should be fed individually, the allowance for each being measured or weighed and the amount fed depending on the size and vigor of the

[19]Ky. Bul. 171.

individual. A good plan to follow is to feed whole milk at the rate of 1 lb. daily for each 8 to 10 lbs. the calf weighs. Weak calves should be fed milk at the lesser rate. The allowance should not usually exceed 12 lbs., even for a large and vigorous calf.

688. Feeding skim milk.—When the calf is 2 to 4 weeks old, the exact age depending on its vigor, skim milk may gradually replace the whole milk, 7 to 10 days being required to get the calf on skim milk alone. With cows giving very rich milk, some prefer to dilute with skim milk from the start. In the case of very valuable calves, breeders often feed some whole milk for 2 months or longer.

After the calf has been changed entirely to skim milk, the allowance may be increased very gradually if the calf is doing well. Not over 15 to 16 lbs. of skim milk daily is needed to ensure good development, but if an abundance of skim milk is available after any growing pigs on the farm have their share of this valuable feed, large vigorous calves may be fed somewhat larger amounts. The allowance should not exceed 18 lbs. daily until the calf is 6 weeks old, and only in rare cases should over 20 lbs. be fed at any time.

Skim milk is at its best when, still warm, it goes at once from the farm separator to the calf. Milk held for any length of time or chilled should always be warmed to 100° F. before feeding. In cold weather it is not safe to rely on the skim milk being warm enough as it comes from the separator, but the thermometer should be used. When the calf is 3 to 4 months old, it can usually be accustomed to cooler milk provided the temperature is reasonably uniform. The calf pails in which the milk is fed should be kept scrupulously clean, a good rule being to cleanse them as thoroly as the milk pails. Feeding skim milk which is sour, stale, and teeming with undesirable bacteria is a frequent cause of scours. Trials by the United States Department of Agriculture[20] indicate that satisfactory results may be secured in summer with clean milk when soured quickly by lactic acid bacteria, such as are used in starters for butter making. In winter some of the calves showed a distaste for the sour milk. Skim-milk feeding should usually continue until the calf is 7 to 8 months old, but when the supply of milk is scant a thrifty calf may be weaned after 2 to 3 months, provided good substitutes for milk are fed, as shown later. (**696-8**)

At feeding time hand-reared calves should be confined in stanchions, to remain for a time after the milk is drunk until they consume their concentrate allowance and overcome the desire to suck each other's ears or udders. When this precaution is neglected, the shape of the udder may be injured or a heifer may later persist in sucking herself or others.

689. Pasteurizing creamery skim milk.—Patrons delivering whole milk to creameries should insist that all skim milk be pasteurized before it is returned to the farm. This precaution keeps the milk sweet and kills the

[20]Breeder's Gazette, 66, 1914, p. 17.

disease-producing bacteria, thereby lessening trouble from scours and preventing the possible introduction of tuberculosis and other diseases.[21] Whey and buttermilk should likewise be pasteurized before being fed.

690. Feeding concentrates.—When 1 to 2 weeks old, the calf should be taught to eat concentrates. Such feeds as corn meal, ground oats with the hulls sifted out, barley meal, kafir meal, wheat bran, red dog flour, and linseed meal, alone or in mixture, may be placed in the bottom of the pail after the calf has finished drinking its milk. Some add the concentrates to the milk, but this is inadvisable as the meal is then less thoroly mixed with the saliva. The addition of such concentrates as bran or linseed meal to the farm grains may be helpful in teaching the calf to eat. The dull calf may be taught to eat the meal by rubbing a little on its muzzle when it is thru drinking milk. Having learned the taste of the meal, the calf should thereafter be fed its allowance dry from a convenient feed box. Until it becomes accustomed to the new article of diet, a supply of meal may be kept before it. After this, however, only as much should be fed as will be eaten up, and the feed box should be cleaned out regularly. At 6 weeks the calf will usually eat 0.5 lb. of concentrates a day; at 2 months, about 1 lb.; and at 3 months, 2 lbs. Unless it is desired to push the animal ahead rapidly not over 2 or 3 lbs. need be fed the skim-milk calf up to 6 months.

691. Concentrates for skim milk calves.—It has been pointed out previously in this chapter that entirely satisfactory results are secured when only farm-grown grains are fed as the concentrates, if the calves have plenty of skim milk. (682) A mixture of equal parts of corn and oats is often fed skim milk calves. However, such concentrate mixtures as the following are somewhat more palatable and are preferred by many dairymen. It will be noted that these consist most largely of the cereal grains.

(1) Corn, 3 parts; oats, 3 parts; wheat bran, 1 part; linseed meal, 1 part. (2) Equal parts oats, bran, and corn or ground barley. (3) Oats, 5 parts; corn, 1 part; bran, 3 parts; linseed meal, 1 part.

The Guernsey Breeder's Journal,[22] on gathering the experience of over 100 breeders of Guernsey cattle, found that the following were used as supplements to skim milk:

Thirteen fed a mixture of equal parts oats and wheat bran; 11, a mixture of 5 parts oats, 3 parts bran, 1 part linseed meal, and 1 part corn meal; 8, whole oats; 7, ground oats; 7, oats, bran, and linseed meal; 6, corn and oats; 6, the concentrate mixture given the dairy herd; 5, corn meal, oats, and bran; 4, corn meal, bran, and linseed meal; and others, mixtures of wheat middlings and linseed meal, of corn meal and linseed meal, of hominy and bran, and of corn and bran.

The feeder thus has an extended list of successful mixtures from which to select the one most economical for his local conditions.

[21]Dean, Ontario Agr. Col. Rpt. 1899; Otis, Kan. Bul. 126.

[22]Guernsey Breeder's Jour., May 1915, p. 38.

692. Hay for calves.—Calves begin to eat hay at about the same age as they do grain, consuming nearly the same quantity of each at first. As they grow and the paunch develops, the proportion of roughage to concentrates should be increased until when 6 months old they will be consuming about 3 times as much hay as grain. The majority of dairymen prefer clover or alfalfa hay, but the allowance of these should be restricted when the calves are young, to avoid scouring. Some prefer bluegrass, native, or mixed hay for the first two or three months because with these there is less danger from scours. The growing heifer should be encouraged to eat a goodly amount of hay in order to develop the roomy digestive tract desired in the dairy cow. Uneaten roughage should be removed from the rack or manger before the next feeding time, for calves dislike hay which has been "blown on."

Tho it would not be economical to raise calves without roughage, the question as to whether they can be reared on milk alone or milk and grain is of much scientific interest. Most attempts have ended in failure, and it has been assumed that perhaps some coarse feed is needed to fill the first three stomachs before they can develop properly. Sanborn[23] maintained a calf for 6 weeks on grain and milk, when, thru its craving for roughage, the sawdust used for bedding was eaten, causing death. Davenport at the Illinois Station[24] and McCandlish at the Iowa Station[25] were also unable to rear calves on milk alone or milk and grain. More recently this problem has been studied by Eckles at the Minnesota Station[26] and Fitch, Hughes and Cave at the Kansas Station.[27] In trials by Eckles calves could not be raised on milk even when vitamines were added. On the other hand, when calcium was added to the milk, complete recovery was secured. This suggests that what is needed in an exclusive milk ration is not the bulk of the roughage but the additional calcium supplied by the usual roughages. In the Kansas trials calves could not be raised on milk from cows fed rations low in the fat-soluble and the water-soluble vitamines. On the other hand, calves were raised quite successfully on milk from cows fed normal well-balanced rations, even when care was taken to keep the calves muzzled so they could take no other feed. Salt was fed the calves frequently.

693. Succulent feeds.—A small amount of silage, free from mold and not too acid, may be fed to calves after they are 2 months old. From trials at the Connecticut (Storrs) Station,[28] White and Kuelling conclude there is no advantage in offering it to them earlier, as the quantity they will eat is small and with many rations, especially of a laxative nature, it will increase the danger of scours. They state that vigorous calves will consume about the following amounts of silage per head daily; second to third month, 2 lbs.; third to fourth month, 5 lbs.; fourth to fifth month, 7 lbs.; fifth to sixth month, 10 lbs. Should the calves not be gaining

[23]Utah Bul. 21.
[24]Ill. Bul. 46.
[25]Iowa Res. Bul. 48.
[26]Information to the authors.
[27]Information to the authors.
[28]Conn. (Storrs) Bul. 102.

rapidly enough, the allowance of silage should be restricted, leaving more capacity for concentrates and hay.

Roots are also a satisfactory succulent feed, and pasture is excellent for calves old enough to make good use of it. To avoid scours, they should be accustomed to grass gradually, being turned to pasture for only an hour the first day. Another method is to accustom them to green feed by giving increasing allowances of soilage before turning to pasture. It is well not to turn spring or summer calves to pasture until they are 2 to 4 months old, for there is less trouble from scours and the young things suffer less from the flies and heat.

694. Normal growth of dairy calves.—In order to obtain information on the weight and the height at the withers of heifers fed according to good dairy practice, Eckles weighed and measured the pure-bred Ayrshire, Holstein, Jersey, and dairy Shorthorn heifers in the herd at the Missouri Station[29] at monthly intervals. His data, condensed in the following table, provide a convenient standard for any one to use in determining whether individuals of these breeds are making satisfactory growth. The Jerseys were of the "American type" or carried no more than one-quarter blood of the smaller "Island type."

Normal growth in weight and height of dairy heifers

Age	Ayrshire		Holstein		Jersey		Shorthorn	
	Weight	Height at withers	Weight	Height at withers	Weight	Height at withers	Weight	Height at withers
Months	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Inches
Birth	69	.....	90	28.27	55	26.02	73	.....
2	128	29.53	157	32.28	105	29.41	133	32.09
4	218	33.15	249	36.22	174	33.03	225	35.79
6	286	36.46	349	39.72	260	36.89	316	38.46
8	336	38.50	425	42.17	340	39.29	419	41.14
10	406	39.68	501	43.78	407	41.34	538	43.27
12	456	40.75	558	44.88	456	42.64	547	44.41
14	533	42.05	596	46.22	503	43.86	579	45.43
16	560	42.72	643	47.36	533	44.65	627	47.01
18	604	43.78	686	47.95	572	45.51	668	47.72
24	759	45.87	841	49.80	716	47.40	845	49.84
30	...	47.17	1021	51.46	...	48.27	...	51.26
36	...	47.91	....	52.28	...	48.90	...	52.05
48	...	48.50	....	53.11	...	49.45	...	53.54

It will be noted that at one year of age the Aryshire heifers averaged 456 lbs. in weight; the Holsteins, 558 lbs.; the Jerseys, 456 lbs.; and the Shorthorns, 547 lbs. During the first year the heifers of all the breeds studied gained on the average over 1 lb. per head daily, the average daily gain of the Holsteins, which was the largest, being 1.28 lbs. During the second year the average daily gains of the various breeds ranged from 0.71 lb. in the case of the Jerseys to 0.83 lb. in the case of the Ayrshires.

[29]Mo. Res. Bul. 36.

II. Raising Calves On Skim-milk Substitutes

Increasing numbers of dairymen thruout the country are selling whole milk for city consumption, for cheese making, or for the manufacture of condensed and evaporated milk. Because it is too expensive to rear the calves on whole milk alone, many of these men sell the heifer calves from even their best cows for veal and depend upon buying cows to replenish their herds. Since this practice prevents any herd improvement, the successful raising of calves on skim-milk substitutes is a question of prime importance.

695. Buttermilk and whey.—Where available, fresh buttermilk is perhaps the best substitute for skim milk, but the watery slop sometimes obtained from creameries, often from filthy tanks, should be avoided, as such material is almost sure to cause scours. At the Kansas Station[30] Otis found that buttermilk gave slightly less returns with calves than skim milk but caused less trouble from scours. (**267**)

Tho whey-fed calves will not usually make quite as rapid gains as those fed skim milk, whey can be successfully used for calf feeding, if it is obtained fresh from the cheese vat and is fed at blood temperature. It must be borne in mind that most of the protein has been removed in cheesemaking, and therefore whey is not a protein-rich feed like skim milk. Hence, it should be supplemented by a concentrate mixture supplying plenty of protein. To avoid the introduction of tuberculosis and other diseases, whey should always be pasteurized before being returned to the farm. Whey which is allowed to ferment and putrefy in dirty whey tanks can not be successfully used for calf feeding, but whey soured under sanitary conditions may be fed, if sour whey is fed each day. Changing from sweet whey one day to sour whey the next may cause scours.

As an example of the results which may be secured with whey, a trial at the Wisconsin Station[31] by Morrison, Humphrey, and Hulce may be mentioned. At 3 weeks of age, 8 calves were gradually changed from whole milk to separated whey, 10 days being taken for the change. In addition the calves were fed a protein-rich concentrate mixture, consisting of 30 parts ground corn, 30 parts standard middlings, and 40 parts of linseed meal, with legume hay for roughage. The allowance of whey was gradually increased to 14 lbs. per head daily at 6 weeks of age. These calves gained on the average 1.48 lbs. per head daily during the trial, which lasted 6 months, and were vigorous and thrifty. Calves fed a liberal allowance of skim milk made slightly larger gains, 1.68 lbs. per head daily. Satisfactory results have also been secured with whey in other trials[32] when properly fed. (**268**)

696. Raising calves on a minimum amount of skim milk.—Calves raised on skim milk do best when skim milk feeding is continued until they are

[30]Kan. Bul. 126. [31]Wis. Bul. 339, pp. 133-4.

[32]Paterson, West of Scotland Agr. College, Rpt. 15, 1918; Otis, Kan. Bul. 126.

7 to 8 months old, but if only a limited amount is available, quite satisfactory results will be secured if they are weaned when only 2 to 3 months old and thereafter fed only a suitable concentrate mixture furnishing ample protein, along with legume hay and perhaps silage. This is shown in trials by Fraser and Brand at the Illinois Station[33] and Swett at the Missouri Station.[34] Starting when the calves were 2 weeks old or less, they were very gradually changed from whole milk to skim milk. Skim milk feeding was continued until the calves were 45 to 65 days old, when the amount was gradually reduced, and after about 10 days no more milk was fed. The calves were fed liberal allowances of concentrates and also legume hay. In the Missouri trials a concentrate mixture of 4 parts corn, 1 part wheat bran, and 1 part linseed meal was very satisfactory with alfalfa hay. When timothy hay replaced the alfalfa, poor results followed. Calves raised by this system in the Illinois trials required only 137 to 167 lbs. of whole milk (after the milk was fit for human use) and 378 to 491 lbs. of skim milk. They were rather thin for a time, but after being kept on pasture with a limited allowance of grain until 6 months old, all were in thrifty condition, and later several developed into high producing cows.

697. Raising calves on a minimum of whole milk.—When there is no skim milk, buttermilk, or whey available for feeding the calves, a method similar to that just outlined may be followed. The calf is given a good start on whole milk and then at the age of about 45 days, if it is thrifty and vigorous, the allowance of milk may be gradually reduced, and no more milk fed after the calf is 55 to 60 days old. This method has been used with satisfactory results in trials by Hulce and Nevens at the Illinois Station,[35] and by Eckles at the Minnesota Station.[36] In the Illinois trials dairy calves of the larger breeds were raised satisfactorily on a total of only 400 lbs. of whole milk, when they had liberal amounts of concentrates and legume hay. Weak individuals or those which do not take readily to concentrates need milk for a longer time. It is unnecessary to feed the concentrate mixture as a slop, or to cook it. However, when a minimum amount of milk is fed, careful and intelligent feeding and management are required for success.

In trials at the Connecticut (Storrs) Station[37] by White and Kuelling calves were changed when 3 weeks old or more to milk diluted with 3 times the amount of water. The calves were fed daily 3.5 lbs. of milk in this form till they were 6 months old, consuming in this time a total of 700 to 800 lbs. of milk. The small amount of milk was thus diluted so that it would be more completely consumed from the pails and also so that it would better satisfy the calf by filling its stomach. Legume hay and a liberal amount of concentrates were fed in addition. Calves thus fed made better gains than others fed a commercial calf meal.

[33]Ill. Bul. 164.
[34]Mo. Cir. 88.
[35]Ill. Cir. 202.
[36]Information to the authors.
[37]Conn. (Storrs) Bul. 102.

698. Substitutes for milk.—Several different concentrate mixtures have been used with more or less success as substitutes for milk in calf feeding. While carbonaceous grains are better supplements to skim milk than are concentrates rich in protein, substitutes for milk must supply an abundance of protein, as does milk itself. At the Pennsylvania Station[38] Hayward fed calves whole milk for 7 to 10 days and then gradually substituted a home-mixed calf meal consisting of 30 parts wheat flour, 25 parts cocoanut meal, 20 parts skim-milk powder, 10 parts linseed meal, and 2 parts dried blood, the mixture costing about 3 cents per pound. One pound of the mixed meal was added to 6 lbs. of hot water, and after stirring for a few minutes, cooled to blood heat before feeding. With careful feeding the calves receiving the calf meal made as good growth as others fed skim milk. Hayward points out that calves raised upon a milk substitute should have warm, dry quarters as they are apt to be less resistant to disease than milk-fed calves.

At the North Carolina Station[39] Michels obtained satisfactory results with rolled oats as a substitute for skim milk, while Hooper at the Kentucky Station[40] found calves reared on rolled oats grew less vigorously than those fed skim milk.

At the Indiana Station[41] Hunziker and Caldwell fed 2 lots, each of 10 calves, for 6 months from birth, to test the value of home-mixed calf meal consisting of equal parts of hominy meal, linseed meal, red dog flour, and blood meal. Both lots were fed ground oats and corn, alfalfa hay, and corn silage. The calf-meal lot received 1.25 lbs. meal and 1.25 lbs. whole milk on the average per head daily, and the skim-milk lot, 10.85 lbs. skim milk and 0.76 lb. whole milk on the average. The calves fed the calf meal, tho making smaller gains than those fed skim milk, were thrifty and vigorous at the end of the trial.

In later trials at the same Station[42] it was found that a considerable part of the protein in dried blood was not digested by calves. Accordingly a calf meal was prepared by mixing 8 parts ground corn, 1 part linseed meal, and 12 parts fresh liquid beef blood, and then drying this mixture at a temperature not above 140° F., so as not to coagulate the blood protein. This calf meal was fed at the rate of 0.4 lb. per 100 lbs. live weight, being diluted to 10 times its weight with water. Spitzer and Carr[43] fed a lot of 12 calves the calf meal, with clover hay and a mixture of equal parts ground corn and ground oats. These calves gained 1.18 lbs. per head daily during a period of 140 days, while a lot fed skim milk in place of the calf meal gained 1.73 lbs. Later, when turned on pasture, the lot which had previously been fed calf meal made nearly as rapid gains as the skim-milk calves. When 18 months old, the calf-meal animals averaged 475 lbs. in weight, while the skim milk calves averaged 594 lbs.

[38]Penn. Bul. 60.
[39]N. C. Bul. 199.
[40]Ky. Bul. 171.
[41]Ind. Bul. 193.
[42]Jour. Biol. Chem. 28, 1917, pp. 501-9.
[43]Ind. Bul. 246.

Lindsey reared calves at the Massachusetts Station[44] on two proprietary calf meals, Hayward's home-mixed calf meal, and various other home-mixed meals, in comparison with calves fed an abundance of skim milk, ordinary grains, and hay. The calves raised on the milk substitutes were given 3 to 5 quarts of skim milk for the first 3 to 4 months, as he found that putting the calves too early on an exclusive diet of calf meal was likely to produce serious digestive disturbances. This method was satisfactory, tho the calves fed the calf meals made somewhat smaller gains than those given an abundance of skim milk. Lindsey secured good results with a home-mixed meal consisting of oatmeal, 22 lbs.; flaxseed meal, 10 lbs.; flour middlings, 5 lbs.; fine corn meal, 11 lbs.; blood flour, 1.5 lbs.; salt, 0.5 lb. A meal consisting of oatmeal, 35 lbs.; barley malt, 12.5 lbs.; blood flour, 1.5 lbs.; potassium bicarbonate, 0.5 lb.; and salt, 0.5 lb. was also satisfactory.

It is quite probable that the difficulty in raising calves on milk substitutes is due to the fact that the substitutes furnish proteins of poorer quality for growth than the proteins of milk, or else they are deficient in vitamines. (**118, 104**)

Dried or powdered skim milk and semi-solid buttermilk are excellent skim milk substitutes when they can be secured at prices which make their use economical. One pound of dried skim milk, mixed with 9 lbs. of water, will be about equal in feeding value to 10 lbs. of skim milk. Semi-solid buttermilk is only about 40 per ct. as concentrated as dried skim milk.

699. Proprietary calf meals.—There are on the market several calf meals, which are more or less complex mixtures of such feeds as linseed meal or flaxseed meal, ground cereals, and wheat by-products, with or without dried milk, casein, and mild drugs. (**288, 292**) These meals are fairly satisfactory substitutes for skim milk, but apparently give no better returns than home-mixed meals that are much less expensive.[45] Even the best calf meals, either home-mixed or proprietary, are most satisfactory when used as only a partial substitute for milk until the calves are at least 2 months old.

III. General Problems in Raising Heifers

700. Precautions in rearing calves.—In addition to suitable feed intelligently supplied, attention to the following points is necessary for success in rearing calves: The stable should be well lighted and ventilated and reasonably warm in winter. Cold drafts must be avoided. The stalls must be kept clean and should be well-bedded. The calves should be protected from cold cement floors by wood overlays. In all

[44]Mass. Bul. 164.

[45]Dean, Ontario Agr. Col. Rpts., 1900, 1905; Savage and Tailby, N. Y. (Cornell) Buls. 269, 304; Hunziker and Caldwell, Ind. Bul. 193; White and Kuelling, Conn. (Storrs) Bul. 102.

cases the calves should be fed at regular intervals and any increase or change in the feed should be made gradually. Water and salt should always be supplied. In summer shade should be provided for calves on pasture. The feeder should watch for any signs of scours and at once take suitable measures to overcome the trouble. If necessary the calves should be treated for lice or ringworm.

701. Birth weights of dairy calves.—The following table shows the birth weight of dairy calves and the weight of their dams, as determined at the Connecticut (Storrs), Missouri, and Wisconsin Stations:[46]

Birth weights of calves of the dairy breeds

Breeds	Number of calves	Av. weight both sexes Lbs.	Av. weight of dams Lbs.	Weight of calf to weight of dam Per ct.
Jersey	253	55	867	6.3
Guernsey	57	71	996	7.1
Ayrshire	80	72	983	7.3
Dairy Shorthorn	30	73	1,216	6.0
Holstein	229	89	1,137	7.8
Brown Swiss	5	100	1,123	8.9

The male calves of each breed average heavier than female calves. The average difference in weight between the sexes in the data secured at the Missouri Station ranged from 1 lb. in the case of the Shorthorns to 8 lbs. in the case of the Ayrshires. The sire apparently has but little influence upon the size of the calf at birth, if both sire and dam are of the same breed. The nutrition of the cow during gestation does not affect the size of the calf at birth appreciably, unless under extreme conditions which are long continued.

702. Fall calves.—Where cattle are reared under natural conditions, the rule that the young be dropped in the spring will continue, but this practice is not necessarily the most successful in the older sections of the country. Fall-dropped calves come at a time when the small attentions they need can easily be given, and they occupy but little space in barn or shed. Subsisting on the mother's milk, or on skim milk with a little grain and hay, when spring comes the youngsters are old enough to make good use of the pastures and to stand the hot weather and the attacks of flies and mosquitoes.

703. Scours.—The most frequent trouble in raising calves by hand is indigestion, or common scours. This is usually caused by over-feeding, by the use of cold milk or that laden with disease germs, by dirty pails or feed boxes, or by keeping calves in dark, dirty, poorly-ventilated stalls. Each animal should be watched closely for signs of scours, for a severe case gives the calf a setback from which it recovers but slowly. Since soft, foul-smelling dung is often the first indication of trouble, it is well to keep each new-born calf in a pen by itself for 2 to 3 weeks where it can be observed more closely than if it ran with others. At

[46]Summarized by Eckles; Mo. Res. Bul. 35. See also Conn. (Storrs) Rpt. 19.

the first indication of scours the ration should be reduced to less than half the usual amount. Such remedies as castor oil, formalin, and a mixture of salol and bismuth subnitrate, are used with success.

Common scours should be distinguished from contagious, or white, scours, also called calf cholera, which is due to an infection of the navel soon after birth. This most serious disease, from which an animal once affected rarely recovers, may usually be avoided by providing that the calf be dropped in a clean stall or on pasture. When the calf is born in the barn, it is best to wet the navel thoroly with a disinfectant, such as a weak solution of creoline, zenoleum, or bichloride of mercury.

IV. Dairy Heifers

The rearing of the heifer after 6 to 8 months of age is an easy task, and perhaps because for this very reason many are stunted for lack of suitable feed. Since the usefulness of the cow when mature is largely dependent on her proper development before the first calf is dropped, it is important to heed the few essentials in feeding and caring for the heifer.

704. Feeding heifers.—Heifers on good pasture need no additional feed, but one should always be sure that they have ample forage, a point which is often neglected when the pasture becomes parched. In fact heifers are more apt to suffer from neglect in summer than in winter.

In winter there is no better ration than legume hay, silage, and sufficient grain to keep them thrifty and growing vigorously, without becoming too fat. The ration should supply plenty of protein and hence, unless a liberal amount of good legume hay is fed, the concentrate allowance should be richer in protein than is advised for skim milk calves. To develop strong frames, growing cattle must receive liberal amounts of calcium and phosphorus. (**98-9, 119**) However, when legume hay forms one of the main roughages, there will usually be no deficiency of these mineral nutrients. If there is danger of a mineral deficiency in the ration, the heifers should be fed 0.5 to 1 ounce of bone meal, ground limestone, chalk or ground rock phosphate. The nutrient requirements of growing dairy cattle are given in Appendix Table V.

From the extensive experiments of Eckles at the Missouri Station[47] and also trials by Hunt at the Virginia Station[48] and Morrison, Humphrey and Hulce at the Wisconsin Station,[49] the following rations may be recommended for wintering dairy heifers:

1. When legume hay and silage are available, feed all of each of these feeds the heifers will clean up. For animals less than 10 months old feed 2 to 3 lbs. of concentrates a head daily in addition. With alfalfa hay, corn may be fed as the only concentrate. With clover hay or other legume hay lower in protein, some concentrate richer in protein should be added to provide a better balanced ration. From 6 to 10 lbs. of legume

[47]Mo. Bul. 158. [48]Va. Bul. 219. [49]Wis. Bul. 275, pp. 12-13; unpublished data.

hay and 12 to 20 lbs. of silage will be eaten daily, depending on the age and size of the animal. Heifers over 10 months of age, especially of the larger breeds, may make satisfactory gains on silage and legume hay alone if of excellent quality. Usually to keep them growing well, a limited amount of concentrates is added.

2. When legume hay is not available but corn silage is on hand, silage may form the chief roughage. Heifers may make good gains on silage and concentrates with no dry roughage, but often they show a great desire for some dry forage. Hence it is best to feed also some hay, or corn or sorghum fodder or stover. In addition, 2 to 3 lbs. of concentrates should be fed daily, at least one-half of which should be a high protein feed like linseed meal, cottonseed meal, or gluten feed. The rest may be corn, or else barley, oats, or bran, if these feeds are cheaper per pound than corn. Even bright oat straw may form part of the roughage, along with good corn silage. At the Wisconsin Station heifers fed 7 lbs. oat straw and 26 lbs. corn silage a head daily, with 3 lbs. of a concentrate mixture of 2 parts cottonseed meal, 3 parts gluten feed, and 1 part wheat bran, made practically as large gains as others fed alfalfa hay, corn silage, and 2.5 lbs. of a concentrate mixture consisting chiefly of corn. The heifers actually ate but 4.5 lbs. straw a day, being allowed to pick it over and eat the finer parts. The rest was used for bedding. To get heifers to eat unpalatable roughage, diluted molasses may be poured over it. Thus fed on cut corn stover at the Wisconsin Station, molasses was worth as much or more per pound than ground corn.

3. When plenty of legume hay is available, but no silage, a satisfactory ration is legume hay at will (about 12 to 16 lbs. per head daily) with 2 lbs. or more of corn or other grain daily. On legume hay without grain dairy heifers will do fairly well but will not make normal growth.

4. When corn or sorghum fodder or stover and hay from the grasses are the only roughages on hand, it is generally best to purchase enough legume hay to form one-half to one-third the roughage, as without either legume hay or corn silage considerably more concentrates must be fed for even fair results. If only protein-poor roughages are fed, the concentrates should consist chiefly of feeds high in protein.

The effect of liberal versus scant feeding on the development of dairy heifers has been studied in several trials by Eckles at the Missouri Station.[50] Heifer calves fed skim milk (up to 6 months of age), hay and pasture or soiling crops, with no concentrates whatsoever until they calved, made gains considerably under normal both in live weight and in frame. Other heifers fed very liberal rations from birth grew rapidly, and matured at an early age. Growth continued longer with the animals fed the scanty ration, but they never reached full size. One cause of small cows in commercial herds is insufficient feed while they are growing.

Many breeders believe that if a heifer is allowed to become fat she will develop a tendency to use much of her feed for the formation of body

[50]Mo. Res. Bul. 31; Bul. 135.

fat, which will persist when she is in milk. In these trials the heifers which were heavily fed and became fat were possibly slightly inferior in milk production to those receiving less concentrates, tho they lost their excess fat within a short time after calving. Any effect of such overfeeding while young is of little importance in determining the productive capacity of a cow compared with her inherited qualities. The results show, however, that feeding a heavy allowance of concentrates is a much more expensive way of raising heifers than giving them a ration consisting mostly of good roughage.

705. Age to breed.—The age at which heifers should drop their first calves depends on the breed and the size and development of the individual. Jerseys and Guernseys which have been well-fed should usually be bred to calve at 24 to 28 months of age, while the slower maturing Holsteins, Ayrshires, or Brown Swiss should not calve until 28 to 36 months old. Some breeders believe that if the heifer calves at an early age, the tendency to milk production will be intensified, but data secured by Eckles[51] indicate that the highest milk production is usually secured from cows which are well matured before lactation begins. He found that gestation had practically no effect upon the rate of growth of heifers. However, the growth of an animal is checked materially both in skeleton and live weight, as soon as lactation begins, owing to the large amount of nutrients needed for the milk. Therefore, when heifers are fed scanty rations and also bred to calve early, they will be stunted. As a rule, cows that have dropped their first calves at an early age are finer in bone than those which do not calve until more mature.

706. Feed eaten by heifers; cost of rearing.—The feed required in raising heifers and the cost of this and of other items of expense will vary considerably, but from the following data one can closely estimate the probable cost under his local conditions. The following table shows the total amount of feed eaten by heifers during the first and second years, as determined in various trials:[52]

Feed eaten by heifers up to 2 years of age

	Wisconsin Jerseys	Ohio Jerseys	Ohio Holsteins	Illinois Holsteins
First year				
Whole milk, lbs	342	465	499	244
Skim milk, lbs	3,165	2,928	2,786	860
Concentrates, lbs	547	597	656	1,107
Hay or stover, lbs	857	749	797	1,067
Succulent feeds, lbs	353	458	586	1,669
Pasture, days	123	122	128	....
Second year				
Skim milk	....	87	174	....
Concentrates, lbs	....	785	870	...
Hay or other dry fodder, lbs	1,792	1,292	1,651	....
Silage, lbs	3,250	2,426	2,247	....
Pasture, days	171	159	151	....

[51]Mo. Bul. 135.

[52]Bennet and Cooper, U. S. Dept. Agr. Bul. 49; Hayden, Ohio Bul, 289; Hulce and Nevens, Ill. Cir. 202.

In the Ohio experiments the heifers were fed a limited allowance of concentrates during their second year, while in the Wisconsin test they were fed only hay and silage during the winter and grazed on pasture without additional feed in the summer. In the Ohio trials a little skim milk was fed the second year, when there was a surplus. From this table one can readily estimate the feed cost of raising heifers at any time. Under present conditions, this will range from about $50 to $70, depending on local conditions.

To the feed cost must be added the other expenses including initial value of calf, labor, bedding, shelter, interest and taxes, and tools and other miscellaneous expenses. From the total gross cost should be deducted credit for the manure produced. These expenses for grade heifers have been estimated under pre-war conditions as shown in the following table:[53]

Costs other than feed in raising heifers to 2 years

	Ohio	Wisconsin
Initial value of calf	$ 5.00	$ 7.00
Labor	11.50	8.00
Bedding	4.50	3.00
Shelter, insurance, and taxes	8.68	6.03
Miscellaneous expenses	3.00	4.34
	$32.68	$28.37

This table shows that the expenses other than feed in raising dairy heifers to 2 years of age were estimated at $28.37 to $32.68 under pre-war conditions. The credit for manure produced should be at least $8 to $10 on most farms, making the net total cost, including feed, of raising grade dairy heifers about $70 to $90.

V. The Bull

Despite the fact that improvement in the productive capacity of the dairy herd rests as much with the bull as with the cows, the feed and care of the sire at the head of the herd is often neglected. To build up a profitable herd a pure-bred bull which has been bred for dairy production should be selected; this done, he should be so fed as to keep in the best condition for breeding.

707. The young bull.—The same principles apply to the rearing of the bull calf as to the heifer. The bull should be fed from birth to maturity so as to make normal growth, for, while the offspring of an animal which is thrifty but is undersized on account of insufficient feed will not necessarily be smaller than those from a larger sire, such an animal will bring a lower price when it is desired to sell him to another dairyman. From 6 months of age, when the bull calves should be separated from the

[53]Hayden, Ohio Bul. 269; Bennett and Cooper, U. S. D. A., Bul. 49.

heifers, they should be fed a somewhat heavier allowance of grain. The bull should be sufficiently mature for very light service at 10 to 12 months of age. He should be halter broken as a calf and when about 1 year old should have a stout ring inserted in his nose. He should be so handled from calfhood that he will recognize man as his master and should never be given an opportunity to learn his great strength. Stall and fences should always be so strongly built that there is no possibility of his learning how to break loose.

708. Feed and care of the bull.—The ration for the bull in full service should be about the same as for a dairy cow in milk. He should be given good legume hay or hay from mixed legumes and grasses and fed from 4 to 8 lbs. of concentrates, supplying an ample amount of protein. When idle or but in partial service less concentrates will be required. Some breeders hold that feeding corn silage impairs the bull's breeding powers and therefore prefer roots. However, other men have had good results when they have fed bulls 10 to 15 lbs. of silage per day in a properly balanced ration.

Except in severe climates the best quarters for the bull are an open shed with an adjoining paddock where he may exercise. Tho this open-air treatment is admirable for the health of the animal, it results in a heavier and rougher coat of hair, and hence breeders offering animals for sale usually prefer to keep the bulls in comfortable box stalls, turning them out only on fair days. Rather than confine the bull in isolation, it is well to have his stall so located and built that he can see the other members of the herd. The hoofs of the bull spending most of his time in the stall need regular trimming. The bull should be tied by a strong halter to one end of the manger and by his ring to the other end, so that the attendant may approach him from either side without danger. The bull should be dehorned and should always be handled with a strong, safe staff. Even with a quiet, peaceable bull safety lies only in handling him without displaying fear and yet as if he were watching for an opportunity to gore his attendant. Nearly all the accidents occur with "quiet" bulls that have been too much trusted.

To maintain health and virility, the bull must have ample exercise. This is perhaps most conveniently furnished by a tread power, where he may run the separator, pump water, do other useful work, or run the power for exercise only. Many declare that the purchase of a tread power merely to furnish exercise for the bull is a wise investment. Others fix a long sweep on a post and tie the bull at the end, allowing him to walk around the circle. Another device is a light cable stretched between 2 high posts, the bull being attached to it by a sliding chain so that he is able to walk back and forth the length of the cable. The bull may also be harnessed and hitched to cart or wagon for such odd jobs as hauling manure or feed. Whatever the plan adopted, it is

essential that the bull receive ample and regular exercise, else he is almost certain to develop an ugly disposition and may become impotent.

A good sire should be retained in the herd until it is necessary to make a change to prevent too close breeding. He should then, if still potent, be sold to some other breeder.

No commoner mistake is made than discarding a likely sire at 3 to 4 years of age, before his heifers have come into milk to demonstrate how valuable a sire he may be.

A Prosperous Corn-belt Beef Farm

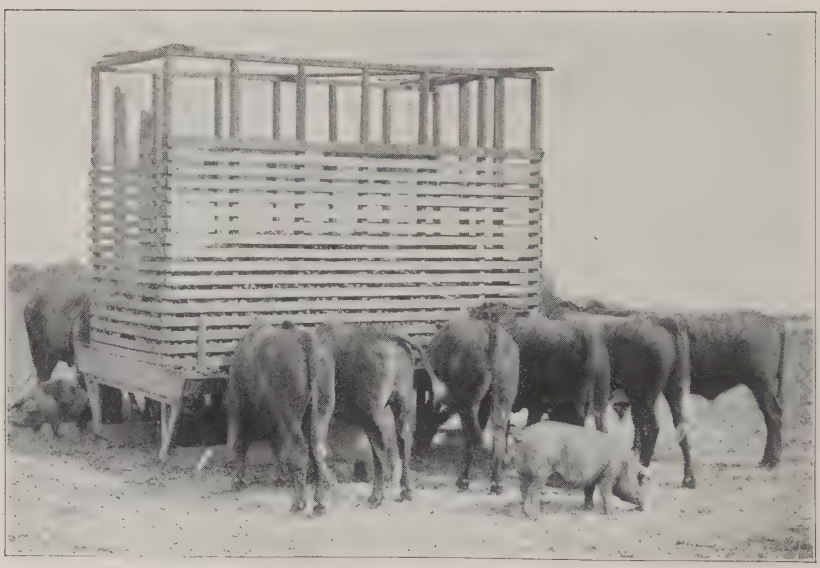
On the left is the well-bred herd of beef cattle, and near the barn are the hogs. Note the open feeding shed at the right. The silo is not shown in this view. (From Wisconsin Station.)

Beef Cattle Utilize Rough Land

Breeding herds of beef cattle can be maintained cheaply on land too rough or stony for tillage. (From U. S. Department of Agriculture.)

HAND-FEEDING STEERS EAR CORN ON PASTURE

Commonly the concentrates are fed to cattle on pasture in broad troughs or "feed bunks." Hand-feeding cattle is a more common practice than self-feeding.



SELF-FEEDING EAR CORN TO STEERS ON PASTURE

Self-feeders are sometimes used for fattening cattle after they are on full feed.

CHAPTER XXVI

GENERAL PROBLEMS IN BEEF PRODUCTION

The years of 1920 and 1921 were one of the most critical periods in the history of beef production in this country. To meet the war-time urge for more beef for export, the number of beef cattle was increased; then came the business depression thruout the world. Consequently, the exports of beef were seriously reduced and the domestic demand likewise diminished. As a result of these conditions, which were the aftermath of the World War, the prices for beef cattle fell to levels which have brought heavy losses to beef producers thruout the country.

With a return of conditions to normal, without question reasonable profits will again be realized in beef production. As financial conditions in foreign countries improve, the demand for beef for export will increase, and as the business depression in the United States is overcome, the domestic consuming capacity of our own population for beef and other meats will become greater.

Fortunately for the American public, which would be exceedingly loath to give up beef as a common article of diet, our experiment stations have pointed out the manner in which the cost of beef production may be lowered to where it yields a reasonable profit to the farmer without the finished product being unduly costly to the consumer. The trials reviewed in these chapters show how the breeding herd may be maintained cheaply, utilizing the roughage which would otherwise be wasted on the farm, and the steer finished for market on a much smaller allowance of concentrates than was formerly believed to be necessary.

Beef production has naturally become separated to a considerable extent into two distinct phases. In sections where the land is unsuited for tillage, either by reason of its rough nature or deficient rainfall, breeding herds are maintained and the cattle raised to be sold as feeder steers. On the other hand, in the corn belt, where land is high in price, the majority of the steers which are fattened for market are not raised by the men who finish them, but are shipped in from the range districts.

A few years ago the steer feeding business had largely passed into the hands of professional feeders who fattened several carloads each year. In many instances they made little use of the manure produced, and purchased much of their feed. On such a basis the enterprise was highly speculative. Now, however, the practice has become common for farmers in the corn-belt and some other sections to fatten a carload or two of steers each year, primarily to provide a farm market for their grain and

roughage, and in this manner to conserve soil fertility. (436) Cattle feeding conducted on this basis, where full value can be secured from the manure produced and where most of the feed is grown on the farm, is far less speculative than when carried on by the large-scale operators.

I. General Factors Influencing Beef Production

709. Margin.—Under usual conditions, the feed consumed by fattening cattle or sheep per 100 lbs. of gain costs more than the selling price per cwt. of the finished animal. With normal market conditions, this difference is offset by the fattened animals selling for a higher price per 100 lbs. than was paid for the same animals as feeders. The difference between the cost per cwt. of the feeder and the selling price per cwt. of the same animal when fattened is called the *margin*. The principle of the margin may be illustrated thus: If a 900-lb. steer costs $7.00 per cwt. when placed in the feed lot, its total cost is $63.00. If during fattening it gains 300 lbs. at a feed cost of $36.00, each cwt. of gain has cost $12.00. Assuming that the manure produced by the steers and the pork made by the pigs following the steers will pay for the labor and the miscellaneous expenses, the steer, now weighing 1,200 lbs., has cost $99.00, and accordingly must bring $8.25 per cwt. at the feed lot to even the transaction. The margin will be $1.25, the difference between $8.25 and $7.00.

On account of the high cost of the gains, under all usual conditions a margin must be secured in fattening cattle or sheep to make a profit or "break even" on the transaction. The term *necessary margin* is used to denote the margin needed to prevent loss. In this case it will be $1.25, the difference between $8.25 and $7.00. The *actual margin* is the difference between the actual selling price and the purchase price.

In figuring out the probable financial outcome in fattening a lot of steers, one must always take into consideration the costs incident to the purchase of the feeder steers and bringing them to the feed lot and also the expense of marketing them after they are fattened, including the cost of shipping, the loss thru the shrinkage in live weight on shipment, and the expenses at the central stock yards, such as yardage fees, cost of feed fed at the stock yards, and commission.

The factors which influence the necessary margin in fattening are: (1) The initial cost of the cattle; (2) their initial weight; (3) the cost of the gains; and (4) the expenses in getting the steers to the feed lot and then to the market, when finished.

Other conditions remaining the same, the higher the initial cost, or purchase price, of the feeder the narrower, or smaller, is the necessary margin. For example, let us assume that this same steer had cost $9.00 per cwt. when placed in the feed lot, in place of $7.00 per cwt. Making the same gain as before and at the same cost for feed, it would have to

sell for $117.00, or $9.75 per cwt. at the feed lot, to break even on the transaction. The necessary margin would then be $9.75 minus $9.00, or only $0.75 per cwt. On the other hand, if the steer had cost $5.00 per cwt., the necessary margin would be $1.75 per cwt.

The heavier the animal when placed on feed the narrower will be the necessary margin, for the increased selling price is secured for a greater number of pounds of initial weight. This factor may be offset, as is shown later, if the heavier cattle are older and hence make more expensive gains.

It is evident that any factor which increases the feed cost of the gains makes necessary a wider margin. The necessary margin is thus greater when feeds are high in price, and is wider with mature animals than with younger ones, which make more economical gains. (**712**) Since gains on grass are usually cheaper than in the dry lot, a wider margin is required for winter feeding than in fattening animals on pasture. (**813**) The higher the degree of finish, or fatness, to which the animals are fed, the more expensive the gains become and the wider the necessary margin. (**713**)

Under conditions from 1900 to 1910 an average margin of about $1.00 per cwt. was needed in fattening 2-year-old steers in summer on pasture, and of about $1.50 per cwt. when they were fattened in winter in the dry lot.[1] Conditions have changed materially since these dates and will vary widely in different sections of the country, depending on the cost of feeds and the distance from the market. Anyone can readily compute the approximate margin which will be required under his local conditions by taking the actual cost of feeders at any given time, the price of the available feeds, and the amounts of feed required for 100 lbs. gain, as shown in this and the following chapter. To the necessary margin thus computed must be added the cost per cwt. of getting the feeder cattle to the feed lot and the cost per cwt. of marketing the fat cattle, including the loss due to the shrinkage in shipment.

710. Feed requirements for fattening cattle.—In Chapter V we have already seen that with mature animals there is comparatively little storage of protein or mineral matter during fattening, and that the ration may have a relatively wide nutritive ratio. (**129**) However, most of the beef cattle in this country are now fattened while they are yet growing. For the fattening of such animals sufficient protein must be provided for the growth in muscle and other protein tissues which takes place as the animals fatten. An extensive survey of feeding trials at the experiment stations shows that for the most rapid gains in fattening 2-year-old steers the nutritive ratio should not be wider than 1:7 to 1:8. Accordingly, in the Morrison feeding standards nutritive ratios no wider than this are advised. Younger steers should receive a slightly larger proportion of protein, as is shown in Appendix Table V. When protein-

[1]Waters, Mo. Bul. 76; Skinner and Cochel, Ind. Cir. 12.

rich feeds are lower in price than carbonaceous feeds, it may be economical to feed much narrower rations than advised in the feeding standards. For example, good results are often secured when cottonseed meal is fed as the only concentrate, the nutritive ratio then being as narrow as 1:3.8.

As is shown later in this chapter, the amount of concentrates to be fed will depend on the rapidity with which it is desired to fatten the cattle, and the degree of finish, or fatness, which the demands of the market make most profitable.

Where fattening cattle are fed common well-balanced rations including silage or legume hay, there will ordinarily be no lack of mineral matter except of common salt. (**98-100**) Furthermore, there will be no deficiency of vitamines in such rations. (**104**) Therefore no particular attention need be paid to these feed constituents for this class of stock. If roughages are fed which are low in calcium, this may be furnished cheaply by adding to the ration one ounce or so per head daily of steamed bone meal, ground limestone, wood ashes, or chalk. There is no necessity of purchasing any expensive proprietary mineral mixtures or vitamine preparations whatsoever.

We have seen in previous chapters that in feeding some classes of animals, especially young pigs not on pasture, the character or quality of the proteins supplied by different feeds is of great importance. For example, a ration of only grain and either linseed meal or wheat middlings furnishes protein so poorly balanced that pigs make very poor growth on it. However, cattle are always fed a large amount of roughage. Therefore, just as with pigs on pasture, the character of the protein supplied by different protein-rich supplements is of little importance when roughages of ordinarily good quality, such as silage or legume hay, are fed. For example, linseed meal, cottonseed meal, and gluten feed are all satisfactory supplements to add to rations of corn or other grain, silage and hay or straw. Consequently, in deciding what supplement to use at any given time, the choice should be based chiefly on the cost per pound of digestible crude protein in the different protein-rich feeds available. (**191-2**) In addition, one should consider the results which have actually been secured with the various supplements in practical feeding trials, as reviewed in the next chapter.

711. Feed and gains from birth.—In his extensive experiments to determine the nutrients required by growing and fattening steers, which were carried on at the Minnesota Station[2] from 1907 to 1916, Haecker recorded all the feed consumed by 5 groups of grade beef-bred steer calves from birth to 2 years of age or over. At first the calves were fed whole milk, but after 2 to 3 weeks they were gradually changed to skim milk. Prairie hay and corn silage were fed as roughages to the steers, with grain, wheat bran, flour middlings, and linseed meal as concentrates. The steers were allowed all the roughage they would consume, but were

[2]Minn. Buls. 155, 193.

fed only a limited amount of concentrates. At no time after weaning were they fed over 1 lb. of concentrates per 100 lbs. live weight. Yet at about 2 years of age they reached a weight of 1,200 lbs. and were sufficiently well fleshed to be ready for market. Some of the steers were continued on trial until they reached 1,500 lbs., to determine the cost of thoroly fattening them. In order to keep a record of all the feed they consumed, part of the steers were never turned to pasture, but were raised and fattened in barn and dry lot. Others were pastured the second summer and then returned to the barn and fattened that winter.

The following table summarizes some of the most important data secured in these investigations:

Feed required for 100 lbs. gain by steers of various ages

Period	Av. daily gain	Feed for 100 Lbs. Gain					Total dig. nutrients per 100 lbs. gain	Feed cost of 100 lbs. gain
		Milk	Skim milk	Concentrates	Hay	Silage		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cents
Steers not pastured								
100– 200 lbs.	0.93	247	1,005	91	103	6	225	7.50
200– 300 lbs.	1.33	...	575	196	232	126	319	4.90
300– 400 lbs.	1.44	...	160	251	291	326	376	5.00
400– 500 lbs.	1.51	...	...	291	322	481	429	5.50
500– 600 lbs.	1.85	...	...	283	314	438	426	5.30
600– 700 lbs.	1.71	...	...	362	440	327	529	6.50
700– 800 lbs.	1.79	...	...	425	480	135	553	7.50
800– 900 lbs.	1.53	...	...	558	550	364	708	9.50
900–1,000 lbs.	1.62	...	...	550	455	715	731	9.30
1,000–1,100 lbs.	1.53	...	...	623	449	876	808	10.00
1,100–1,200 lbs.	1.48	...	...	714	455	899	885	11.20
1,200–1,300 lbs.	....	...	...	821	774	1,050	...	14.40
1,300–1,400 lbs.	....	...	...	870	785	1,200	...	15.20
1,400–1,500 lbs.	....	...	...	911	563	1,746	...	15.40
From calf to 600 lbs.....	1.39	94	339	232	264	279	...	6.30
From calf to 1,200 lbs.....	1.52	42	152	407	385	423	...	7.80
From calf to 1,500 lbs.....	....	33	120	506	454	618	...	9.30
Steers after returning from pasture								
700– 800 lbs.	2.72	...	...	243	210	645	379	4.50
800– 900 lbs.	2.29	...	...	335	233	946	510	5.90
900–1,000 lbs.	1.83	...	...	512	327	1,139	715	7.80
1,000–1,100 lbs.	1.70	...	...	540	358	1,348	796	8.80
1,100–1,200 lbs.	2.00	...	...	520	228	1,170	697	7.80

The daily gains of the steers increased until they reached 600 lbs. in weight, after which they decreased slightly. The amount of feed required for 100 lbs. gain rose steadily as the steers grew and fattened. While only 225 lbs. total digestible nutrients were required for 100 lbs. gain between

the weights of 100 to 200 lbs., over 800 lbs. total digestible nutrients were required for 100 lbs of gain when the steers reached the weight of 1,000 lbs.

The feed cost of 100 lbs. gain was higher for the first period than for those immediately following, due to the whole milk fed. The cost then rose gradually from $4.90 per 100 lbs. gain between 200 and 300 lbs. live weight up to $15.40 between the weights of 1,400 and 1,500 lbs. The feed cost of the gains was especially high after the steers had reached 1,200 lbs., at which time they were sufficiently well fleshed for the market, but not fat enough for "prime" beef. There have been already discussed in Chapter V the various factors which make the gains of young animals less expensive, as is illustrated by these data. (**114, 123**)

The steers which had been turned to pasture made much more rapid and also more economical gains at the same live weight periods than those which had had no pasture. This was because they were more growthy and carried less flesh, and also possibly owing to a greater supply of vitamines or other unknown factors of nutrition which they secured in abundance from the green forage, that put them in the best condition to make profitable gains. From the amounts of feed required for 100 lbs. gain, the approximate cost at local prices for the various periods may readily be determined.

In these investigations by Haecker it was found that the older steers actually stored as much energy in their bodies for each 100 lbs. of total digestible nutrients in the feed they ate, as did the younger steers. However, as the gains in body tissues of the young steers were high in water and low in fat, while the gains of the older steers consisted chiefly of energy-rich fat, much more feed was required by the older steers per 100 lbs. of gain in weight, as has already been pointed out.

In a previous comparison of the economy with which the various farm animals convert their feed into human food, it has been shown that beef cattle rank along with sheep in the economy with which they produce edible meat, and are greatly excelled by swine. (**132**) In these investigations it was found that well-finished 1,200-lb. steers yielded in their carcasses 10.95 lbs. of edible meat and fatty tissues, containing 6.02 lbs. dry matter, for each 100 lbs. total digestible nutrients they had consumed during their growth and fattening.

712. Influence of age on cost of fattening.—On account of the great practical importance of the question, many trials have been conducted to compare the cost of gains and the profits from fattening calves, yearlings, 2-year-olds, and older cattle. In the table on the next page are averaged the results secured in two trials of this nature at the Indiana Station[3] by Skinner and Cochel with well-bred beef steers, fed until each lot would sell as prime beeves. The calves were of the best type and breeding possible to obtain, as it is not practicable to attempt to produce fine yearling beef from inferior calves. The yearlings and 2-year-olds

[3]Ind. Bul. 146.

compared favorably with the calves in capacity and condition at the beginning of each test, tho not of quite such good type.

Fattening calves, yearlings, and 2-year-olds

	Calves	Yearlings	2-year-olds
Av. initial weight, lbs.	518	888	1,067
Length of feeding period, months	9	6.5	6
Av. daily gain, lbs.	1.88	2.22	2.6
Av. total gain, lbs	508	431	471
Av. feed consumed per head:			
Shelled corn, lbs	3,026	3,034	3,212
Cottonseed meal, lbs	445	480	510
Clover hay, lbs	857	714	760
Corn silage, lbs	1,950	2,849	2,700
Feed per 100 lbs. gain by steers:			
Shelled corn, lbs	596	704	681
Cottonseed meal, lbs	88	111	108
Clover hay, lbs	168	165	160
Corn silage, lbs	385	660	573
Feed cost per 100 lbs. gain*	$7.74	$9.09	$9.37
Pork per bushel of corn fed to steers, lbs.*	1.00	1.85	2.50

*Av. of 3 trials.

While it required only 6 months to make the 2-year-old steers fat enough to sell as prime beeves, it took 9 months to finish the rapidly growing calves equally well. Therefore, as the table shows, it required nearly as much feed per head to finish the calves as the 2-year-olds. Tho the daily gains increased with the age of the steers, the older cattle required considerably more feed per 100 lbs. gain, which made their gains more expensive. Other trials by Grisdale at the Ottawa Experimental Farms[4] have shown that the gains of 3-year-olds are still more expensive than those of 2-year-olds. As is usual, the older steers in this trial masticated the shelled corn less thoroly than the younger animals, and hence the pigs following them made more pork for each bushel of corn fed the steers.

Calves usually cost more per 100 lbs. as feeders than do yearlings or 2-year-olds, but when fat sell at about the same price per 100 lbs. as the older animals. This may entirely offset the cheaper gains made by them. For example, in these Indiana trials the 2-year-olds returned the largest and the calves the smallest profit per head. In addition, greater care and skill are required to fatten calves, they do not stand severe weather so well, and they must be fed a larger proportion of grain to roughage than the more mature steers. Furthermore, most of the range steers sold as feeders are not of sufficiently good beef type and conformation to be finished as baby beeves. As is pointed out later, this requires well-bred vigorous beef calves. (**818-9**) For these reasons, the great majority of feeder steers are fattened when 2 years old, tho the tendency toward the fattening of yearlings is increasing. On the other hand, in the corn belt most farmers who raise their own steers on high-priced land find it most

[4]Ottawa Expt. Farms Rpts., 1900-1904.

profitable to produce baby beef, selling the animals when 20 months old or less.

To determine the relative cost of gains by steers of different ages but of the same breeding, Gramlich fed 10 calves and the same number of yearlings and 2-year-olds at the Nebraska Station.[5] All the steers were of the same breeding and had been raised on the same ranch. The steers were all fed for 200 days on rations of shelled corn, linseed meal, alfalfa hay, and corn silage. At the end of this period the 2-year-olds averaged 1,226 lbs., the yearlings, 1,004 lbs., and the calves 781 lbs. The carcasses of the yearlings were ideal, while the 2-year-olds were rather fat and the calves showed a slight lack of finish. During the trial the yearlings and the 2-year-olds made the same gains, 2.21 lbs. per head daily, and the calves gained 2.0 lbs. daily.

The feed cost of 100 lbs. gain was $8.94 for the 2-year-olds, $7.68 for the yearlings, and only $6.93 for the calves. All the steers were purchased for the same price per cwt. as feeders, tho quite commonly calves cost more per cwt. than older steers. At the end of the trial the calves could have been sold for $1.50 less per cwt. and the yearlings for $0.70 less per cwt. than the 2-year-olds and break even on the transaction. The calves actually sold for as high a price as the 2-year-olds and for only 25 cents less than the yearlings. Consequently, while money was lost on the 2-year-olds, owing to the slump in the price of fat cattle in the spring of 1921, the calves and the yearlings returned a profit over the cost of feed and marketing. In a second trial the following year, in which the steers were fed corn and alfalfa hay, similar results were secured.

In a trial at the Kansas Station[6] by McCampbell, Bell, and Winchester, a lot of baby beeves fed for 150 days gained 2.62 lbs. per head daily on a ration of ground corn, linseed meal, alfalfa hay, and sorghum silage, while 2-year-old steers fed the same feeds for 120 days gained 3.11 lbs. per head daily. The feed cost of 100 lbs. gain was 26 per ct. higher for the 2-year-olds than for the calves.

Tho yearlings will usually make a trifle cheaper gains than 2-year-olds, much depends on the condition and type of the cattle, and sometimes the older steers will make the more economical gains. For example, in a trial by Bohstedt at the Ohio Station[7] 2 lots of yearlings, averaging 636 lbs. in weight when placed on feed, gained 2.44 lbs. per head daily, with a feed cost per 100 lbs. gain of $8.14 after crediting the corn utilized by the pigs following the steers. Two-year-olds averaging 921 lbs. in initial weight, gained 2.90 lbs. a head daily at a feed cost per 100 lbs. gain of only $7.75.

713. Influence of degree of fatness.—Experienced cattle feeders know that it never pays to carry fattening cattle to an unnecessarily high "finish," or degree of fatness. This is because gains produced when an animal is already fairly well fleshed are unduly expensive. Impelled by

[5]Information to the authors. [6]Kan. Cir. 77. [7]Information to the authors.

his hearty appetite, a well-fed feeder steer at first makes rapid gains and requires only a moderate amount of feed for a pound of increase in weight. Later, as he becomes fatter, his appetite loses its edge, and he shows a daintiness in taking his food not at first noticed. Every pound of gain now requires much more feed than formerly. This is not only because the steer eats less feed per 1,000 lbs. body weight and hence has less available for making body tissue, but also because the gains at the close of the fattening period are more concentrated; i.e., they contain less water and a larger proportion of fat. (**123**)

An experienced stockman can easily tell the degree of fatness of an animal. On thin cattle the flesh on the back and over the ribs and shoulders is relatively hard and unyielding, while after proper fattening the flesh feels mellow, yet firm and springy. Other indications that a steer is well fattened are a fullness at the root of the tongue, a well-filled flank, and a full "twist" and "cod." If a steer is carried to an extreme degree of fatness, as is often done in fitting for shows, the flesh will be soft and blubbery, due to the large accumulation of fat.

Not only are the gains exceedingly expensive when cattle are carried to extreme fatness, but also carcasses from these animals do not meet the desires of most consumers. The lean meat from such carcasses will, it is true, be of the highest quality, but too large a proportion of the various cuts will consist of masses of fat which are not usually eaten. It has been pointed out in a previous chapter that the primary object of fattening stock for slaughter is the improvement of the quality of the lean meat thru the depositing of fat between the bundles of muscular fibers, and to a less extent within the muscular fibers themselves. This gives the meat from well-fleshed animals the characteristic "marbled" appearance. The accumulation of the separate masses of fat in the carcass is only a necessary accompaniment in the process. (**122**)

Any excess fat beyond that which is required to make the meat attractive, juicy, and well-flavored is waste, because the consumer will generally not eat it, tho it has been a heavy expense to the producer. In former years, when cattle were usually fattened after they reached maturity, it was necessary to carry them to a high finish to make the meat tender and juicy. Now, however, with our changed methods of beef production in which cattle are fattened while yet young and growing, such extreme finishing is no longer needed.

The demand for heavy, highly fattened steers is limited, even on the large central markets, for most consumers can not afford this class of beef. Usually on these markets such steers will bring some premium over those which are well fattened, but not "ripe." However, quite commonly the difference in price is so small that it fails to offset the high cost of carrying the steers to this degree of finish. The wise beef producer will therefore keep posted with reference to the market prices of various grades of cattle and sell his steers just as soon as they are sufficiently well fleshed to return the most profit. While it would be a source of pride

to him to sell a load of steers that would "top the market," he knows that oftentimes this reduces rather than increases the net return.

The wastefulness of carrying cattle to an extreme degree of fatness is well shown in a trial by Trowbridge, Moulton, and Haigh at the Missouri Station[8] in which one steer was slaughtered before fattening, at a weight of 756 lbs., and the entire carcass analyzed. Another was slaughtered after being fed a fattening ration for 153 days, when it weighed 1,266 lbs. and would have graded as a choice steer but lacked 40 to 50 days of feeding of being in prime condition. A third was fed until it reached the weight of 1,805 lbs., when it was in extremely fat condition. Compared with the animal slaughtered before fattening, it was found that the 1,266-lb. steer had stored in its body 152.6 lbs. lean meat and 151.7 lbs. fatty tissue. From this stage of fattening onward the gains are chiefly fatty tissue. Compared with this 1,266-lb. steer, the 1,805-lb. very fat steer had stored 255.5 lbs. more fatty tissue and only 89.5 lbs. more lean meat. Furthermore, for each pound of gain in weight the 1,266-lb. steer had required only 4.51 lbs. digestible organic nutrients in its feed, while the very fat steer had consumed 8.16 lbs. Concerning the economic loss thru fattening animals to such an extreme degree, Moulton well concludes: "As conditions are now, a large amount of the corn produced in the Mississippi Valley is converted into animal fat, which is not used for human food but finds its way into the sewer or soap factory."

714. Length of feeding period.—The length of the feeding period needed to finish cattle depends on the method of feeding followed and on the age and condition of the cattle when placed on feed. When the steers are fed roughage with only a limited allowance of concentrates, the fattening process will take considerably longer than where they are rapidly brought to full feed and then crowded with all the concentrates they will eat. Obviously, much less time is required to finish steers already in good flesh when started on feed than those in leaner condition. Such fleshy feeders are commonly "short-fed;" i.e., fed for 90 to 100 days or less on a heavy allowance of concentrates. Thin steers must be "long-fed;" i.e., fed for a considerably longer period, during the first part of which often little or no grain is fed other than that in the silage. When grain is high in price, long-fed steers may even be fed no other grain thruout the entire fattening period. (**715-6**)

These two methods of beef production were compared in trials during 4 winters by Skinner and Cochel at the Indiana Station.[9] Each winter a lot of fleshy feeders was fed for periods averaging 110 days, while a lot of steers in thinner flesh was fed the same feeds for periods averaging 175 days. As is shown in the following table, the average daily gain of the short-fed steers was 2.81 lbs. and the average gain per head, 307 lbs. The average daily gain of the long-fed steers was 2.46 lbs. and the average gain per head needed to get them to the same finish as the short-fed steers was 431 lbs.

[8]Mo. Res. Bul. 30.

[9]Ind. Buls. 130, 136, 153.

Short-feeding vs. long-feeding steers

	Lot I Short-fed	Lot II Long-fed
Av. weight at beginning, lbs	1,165	1,000
Av. gain per head, lbs	307	431
Av. daily gain, lbs	2.81	2.46
Av. ration:		
Shelled corn, lbs	19.72	16.66
Cottonseed meal, lbs	2.96	2.78
Clover hay, lbs	4.41	4.48
Corn silage, lbs	15.33	14.42
Feed per 100 lbs. gain:		
Shelled corn, lbs	702	678
Cottonseed meal, lbs	106	114
Clover hay, lbs	152	183
Corn silage, lbs	558	584
Feed cost of 100 lbs. gain	$9.03	$9.34
Initial cost of steers per 100 lbs	$4.69	$4.36
Necessary margin	$1.03	$1.61
Necessary selling price	$5.72	$5.97
Actual selling price	$6.31	$6.64
Profit per steer, including pork	$15.27	$16.41

Lot I, the short-fed steers, which were given the heavier and more concentrated ration, made larger gains and at a less feed-cost per 100 lbs. gain. Due to the fact that they were in better flesh, the initial cost of the steers in Lot I was 33 cents per 100 lbs. more than those in Lot II. Because of this and also their heavier initial weight, the smaller amount of gain needed to finish them, and their cheaper gains, they could have been sold without loss on a narrower margin than the long-fed steers. This brought the necessary selling price of Lot I, 25 cents per 100 lbs. lower than that of Lot II. The long-fed steers, however, brought enough more when sold to more than counter-balance this advantage, and hence returned a slightly larger profit, when the pork produced by hogs following was included.

715. Amount of concentrates to feed fattening cattle.—One of the most important matters in cattle feeding is deciding how much grain or other concentrates to feed during the fattening period. Upon a wise decision of this problem depends in no small measure the financial outcome of the feeding operations.

In early years when corn and other grain were usually very cheap in price, fattening cattle were ordinarily fed all the grain they could be induced to eat, after they had been gotten on feed. Quite commonly 2-year-old steers were fed an average of over 20 lbs. of corn a head daily, in addition to hay and other dry roughage. Later, when corn silage came into wide use for fattening cattle, it was found that naturally when steers are fed all they will eat of silage from well-eared corn, they will not consume as much corn grain in addition to the roughage. Usually 2-year-old steers full-fed shelled corn in addition to corn silage, hay, and enough

protein-rich supplement to balance the ration will not eat over 16 to 18 lbs. of corn on the average during the fattening period.

As corn became higher in price it became a matter of importance to determine whether the allowance could not be still further reduced. It was found in several experiments[10] that when first placed on feed, steers would make excellent gains for some time on only corn silage, hay, and 2 to 3 lbs. of some protein-rich supplement. Then as the price of corn and other grain rose to unheard-of levels during the war a number of investigators carried on trials to find if cattle could not be fattened satisfactorily for the large markets without feeding any grain in addition to that in the corn silage. This question is of so much practical importance that 13 trials have already been carried on at 7 different stations in which 2-year-old steers have been fattened on a ration of only corn silage, legume or mixed hay, and 2 to 3 lbs. a head daily of linseed or cottonseed meal, in comparison with others receiving a full feed of shelled corn in addition. The following table summarizes the results of these trials, which were carried on with a total of 222 steers averaging 976 lbs. in weight when placed on feed and fed for an average of 125 days.

Feeding no grain except that in corn silage

Average ration	Daily gain	Feed for 100 lbs. gain			
		Corn	Supplement	Hay	Silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
*Lot I, no shelled corn**					
Supplement, 2.9 lbs.					
Corn silage, 49.3 lbs.					
Hay, 3.8 lbs	2.08	...	144	203	2,441
*Lot II, full feed of corn**					
Shelled corn, 13.7 lbs.					
Supplement, 2.8 lbs.					
Corn silage, 28.4 lbs.					
Hay, 2.9 lbs	2.58	534	112	120	1,134

*Skinner and King, 5 trials (Indiana Buls. 206, 220, 240, 249); Evvard, Dunn, Culbertson, and colleagues, Iowa Station, 2 trials (Information to the authors); also 1 trial each by the following: Peters and Carnes, Minn. Station (Information to the authors); Allison, Mo. Station (Information to the authors); Trowbridge and Fox, Mo. Sta. (Information to the authors); Gramlich, Nebr. Station; Bohstedt, Ohio Station, (Information to the authors); Morrison and Fuller, Wis. Station (Unpublished data).

Experienced feeders have been much surprised to find that steers fed only corn silage, hay and a small allowance of a supplement make such large gains. In these extensive trials Lot I, fed such rations, gained 2.08 lbs. a head daily, a gain which would have been considered most excellent, even on a full feed of corn, before the introduction of the silo and the use of modern well-balanced rations. However, Lot II, full fed on shelled corn in addition, gained just a half pound more a head daily.

Some of these trials were carried on during the war with corn as high as $1.50 per bushel, while others have been conducted since the price of corn fell below pre-war levels. Hence the feed cost of 100 lbs. gain varied widely. On the average, it was $2.29 lower for the steers fed no

[10]Skinner and King, Ind. Buls. 153, 163, 167; Cochel, Penn. Bul. 118; Tomhave and Severson, Penn. Bul. 145.

shelled corn. From the data given in the table, the cost with feeds at local prices can readily be computed. For example, with corn at 56 cents a bushel, cottonseed or linseed meal at $50 a ton, hay at $15 a ton, and silage at $5 a ton, each 100 lbs. gain would cost $11.21 for the steers fed no shelled corn, and $11.86 for those full-fed on corn.

Other factors are fully as important as the cost of the gains in deciding the financial outcome. Much more pork is produced by the pigs following full-fed steers than when no shelled corn is fed the cattle. Furthermore, the full-fed steers reach a better finish and hence bring a higher price on the market. There was not, however, as much difference in the actual selling price in these trials as most experienced cattlemen would have predicted. In fact, the "no corn" steers brought only 72 cents less per cwt. than the others. In several of the trials carried on when corn was high in price, the cost of the gains of the "no corn" steers was enough lower to offset the smaller amount of pork and the lower selling price of the steers. Consequently a larger profit was made when no corn grain was fed in addition to that in the silage.

Trials have been carried on by Tomhave and colleagues at the Pennsylvania Station[11] which have been similar except that corn stover has usually been fed in place of hay. In 6 trials carried on from 1915 to 1922 the "no corn" steers gained 2.12 lbs. a head daily on the average and sold for $10.21 per cwt. Steers fed in addition a liberal feed of corn grain gained only 0.10 lb. more a head daily on the average and brought only 16 cents more per cwt. on the market. In all but one trial the return per steer, including the profit from the pigs following, was greater for the "no corn" cattle.

These trials show clearly that cattle can be fattened sufficiently to sell quite well on the large markets by feeding merely corn silage, hay or other dry roughage, and a little cottonseed or linseed meal to balance the ration. When corn is high in price compared with other feeds, probably for 2-year-old steers such a ration will usually return a greater profit than if a heavy allowance of corn grain is fed in addition. On the other hand, in the corn belt with feeds at pre-war prices or at prices current since 1921, the most profit will usually be made if an allowance of corn is fed in addition to that in the silage.

Another important factor to consider in deciding whether to feed corn grain in addition to that in the silage, is the probable difference in selling price per cwt. there will be for cattle thoroly finished on a liberal allowance of concentrates, and for those only fairly well fleshed. If it seems likely that there will be little premium for well fattened cattle, little grain should be fed unless it is very cheap in price. Calves fed for baby beef should always receive grain in addition to that in the silage (**818-9**), and yearlings are not as well suited to a "no corn" ration as 2-year-olds.

[11]Information to the authors.

716. Feeding limited amounts of corn.—When it seems problematical whether it will be more profitable to feed no corn except that in the silage, or on the other hand, to feed a liberal allowance of corn, a middle course may be taken and a limited amount of corn grain may be supplied the cattle. This method has been tested in a number of trials, in which various amounts of corn grain have been fed. The following table summarizes the results of 9 trials in each of which one lot of 970-lb. steers has been full-fed on shelled corn in addition to corn silage, legume or mixed hay, with a small allowance of cottonseed or linseed meal, while another lot has been fed about half as much corn grain thruout the feeding period, which averaged 131 days in length.

Full feed of corn versus half allowance for fattening steers

Average ration	Daily gain	Feed for 100 lbs. gain			
		Corn	Supplement	Hay	Silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
*Lot I, full feed of corn**					
Shelled corn, 13.4 lbs.					
Supplement, 2.6 lbs.					
Corn silage, 30.3 lbs.					
Hay, 2.4 lbs	2.64	510	101	97	1,178
*Lot II, half feed of corn**					
Shelled corn, 6.7 lbs.					
Supplement, 2.6 lbs.					
Corn silage, 42.2 lbs.					
Hay, 2.6 lbs	2.32	298	117	125	1,887

*Average of 5 trials by Skinner, King, and colleagues (Ind. Buls. 206, 220, 240, 249, 255); 2 by Dunn, Pew, and Evvard (Iowa Bul. 182); 1 by Allison, Mo. Station (Information to the authors); and 1 by Bohstedt, Ohio Station (Information to the authors).

In these trials the steers fed only a half allowance of shelled corn made the very satisfactory gain of 2.32 lbs. a head daily at a feed cost of 86 cents less per 100 lbs. gain than those full fed on shelled corn, and sold for only 43 cents less per cwt. However, this difference in selling price and the difference in the amount of pork produced by the pigs following the steers was great enough to offset the cheaper gains, and the full-fed steers returned a greater profit on the average.

When it seems desirable to limit the amount of corn grain fed fattening cattle, it is best during the first part of the period to feed them only silage and hay, with enough linseed or cottonseed meal to balance the ration. They will make excellent gains on such a ration for some time, and then about 40 to 60 days before they are to be sold, they should be started on corn grain and finished on a full feed of grain. This will produce more rapid gains and a better finish than if no additional corn grain is fed at all. Trials at the Indiana and Missouri Stations[12] show that this method takes less corn than where a half allowance of corn is fed thruout the entire feeding period and yet produces fully as large

[12]Skinner, King, and colleagues, 4 trials, Ind. Buls. 206, 220, 240, 249, 255; Allison, Mo. Station, 1 trial, information to the authors.

gains and as good a finish. Consequently the profit is greater than where a limited amount of corn is fed over the entire period.

717. Self-feeding steers.—Tho self-feeders are not commonly used in fattening steers, they may be used successfully when it is desired to feed them all the concentrates they will consume. Manifestly a self-feeder should not be used when it is desired to limit the grain allowance. As the hopper which holds the grain may be of considerable capacity, it requires less labor to keep it filled than to feed the grain by hand twice a day. Unless chopped or ground hay is mixed with the grain, steers unaccustomed to grain feeding can not be fed by means of a self-feeder until they have been brought to full feed, and then the change must be made with care, or some animals will overeat and "founder." The grain in the self-feeder should be protected from rain and snow and care is necessary to avoid clogging, as an abundance of feed must be available at all times.

In a trial by Mumford and Allison at the Illinois Station[13] one lot of steers was fed whole clover hay and a concentrate mixture of 7 parts ground corn and 1 part linseed meal separately at regular feeding periods twice daily, while another was supplied chopped hay mixed with the concentrates, the whole being fed in a self-feeder to which the cattle had access at all times. The self-fed steers consumed a heavier concentrate allowance and were brought to full feed in a shorter time without any set back from over-eating. Tho consuming more feed, this was more than offset by their larger gains. Even after adding the cost of chopping the hay, the self-fed steers made the cheaper gains. Both systems required about the same amount of labor, but by the use of the self-feeder the necessity for a man skilled in feeding was reduced.

Self-feeding was also compared with hand feeding in 2 trials by Pew, Evvard, and Dunn at the Iowa Station[14] from 1915 to 1917. Each year 2 lots of 2-year-old steers were fattened on shelled corn, linseed meal, corn silage, and alfalfa hay, one lot being fed the corn in a self-feeder after the first 40 to 50 days and the other by hand thruout the trial. The self-fed steers made slightly larger gains and returned the most profit over cost of feed. When corn is high in price compared with other feeds, self-feeding is usually less profitable than limiting the corn.

II. Value of Breed in Beef Making

Everyone with experience in the cattle business knows that "blood tells" in beef production. As the following paragraphs show, compared with scrubs well-bred beef steers (1) make more rapid gains than scrub steers, (2) mature earlier, (3) furnish a higher percentage of dressed carcass, (4) produce a greater proportion of more valuable cuts of meat, (5) have less internal fat, and (6) yield a carcass having a higher quality of meat.

[13]Ill. Bul. 142.

[14]Iowa Bul. 182.

The greater earning capacity of pure-bred or high grade stock over scrubs is well shown in an inquiry recently conducted by the United States Department of Agriculture[15] among 2,000 farmers in 36 states who were the first to enroll in the national "Better Sires—Better Stock" campaign. These men estimated that on the average pure-bred beef cattle had an earning power 36.8 per ct. greater than that of common or scrub stock, based on utility alone and not considering the greater pride and pleasure in caring for well-bred cattle. Those who had formerly had scrub stock and had introduced pure-bred sires on their farms reported an average increase of 48.0 per ct. in financial returns traceable to the use of pure-bred sires. These figures show clearly that no stockman who persists in keeping scrub stock can expect a profit.

718. Rapidity of gains.—Tests at various stations[16] prove that steers of beef breeding and of beef conformation make noticeably more rapid gains than those lacking in these points. This is clearly shown in the trial by Mumford discussed later in this chapter (**724**), and also in experiments by Willson at the Tennessee Station. In the latter experiments steers of very good conformation gained on the average 1.76 lbs. per head daily and those classed as good feeders, 1.60 lbs., while the steers of medium or poor conformation gained only 1.37 lbs. Dairy-bred steers, especially those of the larger breeds, do not necessarily make smaller gains than beef-bred steers, tho from other standpoints they are inferior as beef producers.[17] This is reasonable, for in the development of both the beef and the dairy breeds one of the chief objects has been the securing of animals with large capacity for food and vigorous assimilative power. In these qualities the native, or scrub, steer is apt to be lacking.

It is well known that there is great difference in the capacity of individuals of the same breed to make gains when given the same feeds and fed under the same conditions. An experienced judge of cattle can generally pick out the good gainers from a bunch of feeders, by selecting thrifty appearing animals of good conformation. Such animals are low set, deep, broad, and compact, with roomy digestive tracts and vigorous constitutions. Cattle feeders well know that temperament is of great importance in determining gains in the feed lot; the calm, quiet animal which eats and then lies down is almost sure to outgain the restless, active one.

But little scientific work has yet been done to determine just what points of conformation in cattle are of importance as an indication that an animal will make rapid and economical gains. Severson and Gerlaugh concluded from trials at the Pennsylvania Station[18] that large chest or heart girth is more of an indication of good gaining capacity than cir-

[15]Burch, U. S. D. A., Bur. Anim. Indus., press announcement.

[16]Ill. Bul. 90; Iowa Buls. 20, 28; Kan. Bul. 51; Mich. Buls. 44, 69; Mo. Bul. 23; Ont. Agr. Col. Rpt. 1892; Tenn. Bul. 104.

[17]Mich. Buls. 44, 69; Iowa Bul. 60.

[18]Penn. Rpt. 1916-17, pp. 275-295.

CHAMPIONSHIP THREE-YEAR-OLD STEERS AT THE INTERNATIONAL

Steers of this age are continually becoming more scarce on the market, due to the fact that they produce beef less economically than younger animals.

CHAMPIONSHIP TWO-YEAR-OLD FAT STEERS AT THE INTERNATIONAL

The great majority of experienced farmers who buy feeder steers to fatten prefer 2-year-olds. Many of those who raise their own feeders on high-priced land find it more profitable to fatten the animals as baby beef.

CHAMPIONSHIP YEARLING FAT STEERS AT THE INTERNATIONAL

Yearlings usually make less expensive gains than older steers, but require a somewhat longer feeding period to reach the same finish. The proportion of steers marketed as yearlings has increased considerably in recent years.

A FINE BUNCH OF BABY BEEVES

Blocky calves of good type and conformation must be selected for baby beef production, as others will not usually reach the desired maturity and finish at this early age. (From U. S. Department of Agriculture.)

cumference at the paunch. On the other hand, Smith, Bliss, and Lee concluded from data secured at the Nebraska Station[19] that a large girth at the paunch was a better indication of a good feeder than a large heart girth. In the Pennsylvania studies it was concluded that the length from hip to buttock and the width at the thurls were good indexes of gaining capacity. There was somewhat less correlation between gains and depth of chest, width of fore flank, length of head, height at withers, and width at shoulders. There appeared to be no marked correlation between rate of gain and initial weight of steers of about the same age, the width or height at rear flank, the height at the shoulders, the distance from the chest to the ground, or the length from shoulder to buttock.

719. Early maturity.—The most common claim for superiority with the beef breeds is that such animals mature earlier than others. Experienced feeders know that only the blocky calf of beef conformation is suited for early fattening as baby beef. Tho dairy steers grow rapidly and make large daily gains, they do not become well-finished at as early an age.

720. Yield of dressed carcass.—Without question beef-bred steers carried to the same degree of fatness yield a somewhat higher percentage of dressed carcass than do scrubs or steers of the dairy breeds. However, the condition, or degree of fatness of the animal is more important than breed in determining the yield of dressed carcass. It is possible to secure reasonably high percentages of dressed beef even from steers of inferior breeding, if they are well-finished. There is more difference in the appearance on foot in the feed lot and in the gains during fattening between the well-bred steer and the mongrel, than there is in the carcass when the animals have been well fattened.

According to Wentworth[20] the usual run of steers killed by the Chicago packers will dress about 53 per ct., good to choice steers ranging from 56 to 59 per ct., and steers of extra good show type going from 59 to 63 per ct. The champion steer at the 1920 Fort Worth show dressed 67.48 per ct. and the world's record is on a spayed heifer killed at the Smithfield Fat Stock Show in London, that dressed 76.75 per ct. Fat cows dress about 56 per ct., and canners from 35 to 43 per ct.

721. Proportion of valuable parts and of internal fat.—The trials at the various stations show that the well-finished steer of beef conformation generally yields a somewhat higher percentage of loins and ribs, the most valuable cuts, and less of the cheap parts than do mongrel or dairy steers. This difference is less, however, than many believe. The small difference usually found is due to the fact that the beef steer has a broader back and fuller hind quarters than the native or dairy steer.

There is a more marked difference between the beef-bred steers and either scrubs or dairy steers in the distribution of fat in the body. In the carcass of a well-bred beef steer more of the fat is laid on in the muscular tissues and less is deposited about the internal organs, where its

[19]Nebr. Buls. 132, 151; and information to the authors.

[20]Progressive Beef Cattle Raising, Armour and Co.

only value is as tallow. On the other hand, dairy cattle and also scrubs deposit much fat about the internal organs, and less on the exterior of the body and within the muscular tissues. Fat intimately mingled with the muscular fibers of the lean tissues renders such meat tender, juicy, and toothsome. Placed in separate masses anywhere about the body, and especially within the body cavity, it has but low value. Such storage is doubtless best for animals whose function is milk production, but it is certainly against their highest usefulness for beef. In the above characteristic, we have a remarkable example of specialization for a definite purpose.

722. Quality.—Beyond that which can be expressed in figures or stated percentagely lies that indefinable something described by the word "quality" which enters into all objects of barter. No one can compare a bunch of well-fed beef-bred steers with one representing the dairy breeds or natives without being impressed by a difference not measured by the scales. Speaking of the breed tests at the Iowa Station, Wilson[21] writes: "The carcasses of the dairy breeds lacked in thickness of cuts, and the marbling of the fat and lean was not equal to that of the others (beef breeds)." Georgeson wrote after conducting a trial at the Kansas Station:[22] "The Shorthorns gave the best returns, not simply because the gross weight of their carcasses was greater than that of the scrubs, but also because their meat was esteemed better by experts in the packing-house who were asked to judge of the quality and assign prices." Of a native steer fed in comparison with others of the beef breeds Shaw[23] wrote: "There was a lack of thickness of carcass thruout, the deficiency in the rib and loin being very noticeable, and the absence of what may be termed fleshiness was conspicuous."

The thick-fleshed cuts from well-finished beef steers command a much higher price on the large markets than do the thin-fleshed cuts, thereby giving to the carcass that furnishes them a marked advantage in the market. In the Iowa trial the carcasses of the beef steers were valued by experts at $1.66 per 100 lbs. higher than those of the dairy steers. In the Kansas trial the loins of the best Shorthorns were valued 28 per ct. above those of the natives.

The matter at issue may be illustrated by a condition in the fruit world: No orchardist will hold that the Baldwin apple tree necessarily grows faster than the seedling apple tree, or that it will make wood and fruit on less material from soil and air. Neither will he hold that Baldwin trees necessarily yield more barrels of fruit than seedlings, nor that a given measure of Baldwin apples contains more juice or human food than the same measure of common seedling apples. Fruit growers do rightfully assert, however, that the market wants Baldwin apples and will pay more for them than for common seedling fruit, due to the fact that their quality is generally far superior, and that from this judgment of the market there is no appeal. Beef cattle have been bred for meat

[21]Iowa Bul. 20. [22]Kan. Bul. 51. [23]Ont. Agr. Col. Rpt. 1892.

production—it would be passing strange if they did not excel for that purpose.

723. Amount of feed consumed.—Occasionally the claim is yet advanced that well-bred cattle eat less than natives or scrubs. This opinion is not substantiated by feeding trials nor is it generally held by owners of pure-bred or high-grade stock, who believe rather that the well-bred and well-formed animal has a larger capacity to consume feed and convert it economically into meat.

724. Fattening steers of the various market grades.—The most extensive trial carried on to determine the value of beef breeding in fattening cattle is that of Mumford at the Illinois Station,[24] who fed 16 steers of each of six different market grades the same ration for 179 days. Lot I, fancy selected feeders, were of excellent beef type and conformation and carried nearly 100 per ct. of beef blood. As it was desired that the steers in each lot weigh 900 to 1,000 lbs. when placed on feed, the animals in the higher grades were naturally the youngest, for well-bred and well-developed steers mature earlier and reach a given weight sooner than do scrubs. Thus the steers in Lot I were the youngest steers in the trial, being only 2 years old at the time of marketing. Lot II, choice feeders, were high-grade beef steers possessing large frames and averaging about 6 months older than Lot I. Lot III, good feeders, did not show the quality so manifest in Lots I and II, tho beef blood still predominated and the steers were of better type than the average feeders offered on the central markets. Lot IV, medium feeders, were 3-year olds of mixed breeding, tho carrying some beef blood, and showing coarseness and angularity. Lot V, common feeders, showed little evidence of beef blood. They were rather coarse boned and large headed, were plain thruout, and all showed a lack of quality and conformation. They were the result of indiscriminate breeding and the use of inferior grade bulls. Lot VI, inferior feeders, were scrubs showing no beef blood and were inferior in quality and conformation.

The results secured in the trial are summarized in the following table:

Fattening steers of the various market grades

	Lot I Fancy feeders	Lot II Choice feeders	Lot III Good feeders	Lot IV Medium feeders	Lot V Common feeders	Lot VI Inferior feeders
Wt. at beginning, lbs	935	1,115	1,019	1,022	966	965
Daily gain, lbs	2.57	2.54	2.34	2.13	2.21	1.96
Dry matter in ration per 1,000 lbs. live wt.						
Concentrates, lbs	15.2	16.0	16.0	15.8	15.6	15.2
Roughage, lbs	6.8	7.0	7.0	7.1	7.1	7.0
Dry matter per 100 lbs. gain, lbs	995	1,209	1,208	1,305	1,200	1,293
Dressed carcass, per ct	61.6	61.5	60.7	59.7	59.9	59.4
Caul and rough fat, per ct	9.5	9.7	10.6	10.8	10.1	11.8

[24] Ill. Bul. 90.

The second line of the table shows that the feeders of the three higher grades made noticeably more rapid gains than did the steers of the lower grades. With the exception of Lot I, which was considerably younger, the better-bred steers ate slightly more feed per 1,000 lbs. live weight than those of the lower grades.

Lot I made by far the most economical gains, measured either by the dry matter per 100 lbs. gain or by the feed cost of gains, but this was probably due, for the most part, to the fact that these steers were younger than the others. With the other lots there is no consistent difference in dry matter required per 100 lbs. gain or in the feed cost of the gains. The steers of the better grades yielded a higher percentage of dressed carcass than those of the poorer grades. This was due to their beef conformation and not to any greater degree of finish, for the steers in Lots IV, V, and VI, which were older, were nearer their maximum degree of finish at the end of the trial than the younger steers in Lots I, II, and III. The better steers also had less internal fat but carried a heavier layer of the more valuable surface fat. Tho the lower-grade feeders cost less than the better-bred animals, they were worth correspondingly less when fattened.

On the market there is commonly considerable competition among buyers for feeders of high quality, and hence they often command too high a premium over the plainer feeders to make them the most profitable for the purchaser. Furthermore, when fattened, the better steers will often not command as great a premium per cwt. over the common steers as they did before fattening. For these reasons in recent trials at various stations, common steers have often made more profit than those of better quality.

In a trial by McCampbell and Winchester at the Kansas Station[25] a lot of large, rough, uneven steers was fed in comparison with a lot of even, well-made, smooth steers. The better-built steers made slightly larger gains and their feed cost of 100 lbs. gain was $1.21 less per 100 lbs. than for the rough steers. At the end of the 178-day trial the better steers sold for 50 cents per cwt. more. Taking into consideration all factors, the smooth steers were worth only 64 cents per cwt. more as feeders than the steers of better type.

Quite similar results were secured in Pennsylvania in a comparison of choice feeders and medium feeders by Tomhave, Bentley, and Irving.[26] In this trial the cost of gain was practically the same for both lots. The medium feeders cost $1.25 less per cwt. than the better steers and when fattened sold for only 70 cents per cwt. less. Hence the commoner steers were more profitable. In a Nebraska trial by Gramlich[27] choice feeders gained 2.31 lbs. a head daily at a feed cost per 100 lbs. gain of only $8.08, while plain steers gained only 1.95 lbs. and each 100 lbs. gain cost $9.73. However the cost per cwt. of the plain steers was $1.50 less than for the

[25]Kan. Cir. 92.

[26]Information to the authors.

[27]Information to the authors.

choice feeders, while the selling price was only 75 cents per cwt. less. This made the profit per head slightly larger on the plain steers.

In a Wisconsin trial by Fuller, Morrison, and McQuillen[28] medium feeders made fully as rapid and economical gains as choice feeders, probably due to the fact that they were not quite so fleshy when placed on feed. The choice feeders cost $1.66 more per cwt. when purchased than the other steers and would have had to sell at $1.19 more per cwt. when finished to break even. However, they actually brought only $.72 per cwt. more on the market than the medium feeders. Consequently the financial outcome was better with the feeders of medium grade.

In a trial by Dowell and Flack at the University of Alberta, Canada,[29] common feeders also made about as large gains as those of medium or good type. Their cost per cwt. was $1.62 less than for the good feeders, while their selling price was only 56 cents per cwt. less. Consequently the profit was greater on the commoner cattle. Similar results were secured in a second trial by Dowell and Bowstead in which common feeders were compared with good feeders.

725. The most profitable type of steer.—For the beef producer who raises the animals he fattens, it is evident that well-bred specimens of the beef breeds are the most profitable. The question is more complicated for one who purchases feeders on the market. He must consider the price at which he can secure the various grades and the probable price at which they can be sold when fattened. As Mumford concludes:[30] Opportunities for larger profits, and losses as well, lie with the better grades of feeders, for as a rule the price of common, rough, fat steers fluctuates less than the price for prime steers, and the price of inferior and common feeders varies less than those of the choice and fancy grades. The larger the difference in the price of the various grades of feeders, the greater is the advantage in favor of the commoner grades. On the other hand, the larger the difference between the prices for the various grades of fat steers, the greater is the advantage in favor of the better feeders. When prices rule low for beef cattle and the market is dull or downward, the range of prices between prime steers and common rough steers is narrow, and as a result, condition or fatness is more important than beef blood. On account of the greater speculation involved in feeding prime or choice feeders, Mumford advises the beginner to first handle a few carloads of the commoner kinds, which must be purchased at correspondingly lower prices, since the margin for profit in feeding low-grade cattle is usually slight.

726. Gains of steers of various breeds.—The most extensive data available concerning the gains made by steers of various breeds are furnished by the records of the Smithfield, England, Fat-Stock Show.[31] The following table, compiled by the authors from the London Live Stock Journal, summarizes the data for 20 years, 1895 to 1914:

[28]Unpublished data.

[29]Information to the authors.

[30]Ill. Bul. 90.

[31]London Live Stock Jour. 1895-1914.

Age, weight and daily gain from birth of steers slaughtered at the Smithfield, England, Fat-Stock Show, 1895-1914

Breed	No. of animals	Age	Weight	Av. daily gain	Breed	No. of animals	Age	Weight	Av. daily gain
		Days	Lbs.	Lbs.			Days	Lbs.	Lbs.
Aberdeen-Angus					*Kerry*				
1 year old	93	672	1,416	2.11	1 year old	1	644	658	1.02
2 years old	86	1,025	1,848	1.83	2 years old	4	954	1,134	1.18
3 years old	2	1,269	2,130	1.70	*Red Poll*				
Devon					1 year old	52	659	1,254	1.90
1 year old	91	664	1,216	1.82	2 years old	54	999	1,637	1.64
2 years old	123	993	1,609	1.63	3 years old	3	1,247	1,736	1.38
3 years old	4	1,218	1,753	1.45	*Shorthorn*				
Dexter					1 year old	85	674	1,446	2.14
1 year old	47	630	800	1.27	2 years old	91	1,012	1,901	1.88
2 years old	51	975	1,039	1.06	3 years old	4	1,353	2,363	1.74
Galloway					*Sussex*				
1 year old	72	662	1,229	1.86	1 year old	98	678	1,463	2.17
2 years old	73	1,018	1,655	1.63	2 years old	106	1,015	1,831	1.80
3 years old	2	1,236	1,794	1.44	3 years old	5	1,316	2,019	1.53
Hereford					*Welsh*				
1 year old	77	670	1,426	2.13	1 year old	76	698	1,463	2.09
2 years old	84	999	1,844	1.85	2 years old	90	1,039	1,831	1.76
3 years old	2	1,316	2,066	1.57	3 years old	7	1,231	1,919	1.55
Highland					*Cross-bred*				
1 year old	2	730	1,448	1.98	1 year old	96	682	1,469	2.15
2 years old	71	996	1,498	1.51	2 years old	100	1,006	1,897	1.89
3 years old	75	1,334	1,806	1.35	3 years old	4	1,293	2,076	1.60
4 years old	12	1,704	1,923	1.13					

In the "average daily gain" here given is included in all instances the birth weight of the steer. The table well shows that the daily gain of the highly-fed steer decreases as the animal becomes more mature. The records of the slaughter tests at the Show from 1889 to 1895 show that with steers equally well finished, the more mature the animal, the higher is the percentage of dressed carcass yielded. The average dressing percentage of the 3-year-olds was 68.2 per ct. and of the yearlings 65.6 per ct.

III. Miscellaneous Problems in Beef Production

727. Shelter.—Trials at several stations in this country[32] as well as experiments in Great Britain,[33] in which steers have been fattened in open sheds with adjacent yards in comparison with others housed in barns, show that the fattening steer, consuming an abundant ration, a considerable portion of which is roughage, has no need for warm winter quarters. With such animals sufficient heat is produced in the body thru

[32]Trials at Alabama, Iowa, Kansas, Minnesota, Missouri, Ohio, Pennsylvania, Texas, and Utah Stations. Partially reviewed by Armsby, U. S. Dept. Agr., Bur. Anim. Indus., Bul. 108. See also Penn. Rpt. 1906 and Buls. 88, 102; Ala. Bul. 163; Mo. Bul. 76.

[33]Summarized by Ingle, Trans. Highl. and Agr. Soc. Scotland, 1909.

the mastication, digestion, and assimilation of the food to keep them warm under all ordinary weather conditions without diminishing the amount of net nutrients available for fattening. A reasonable degree of cold is a benefit rather than a detriment, providing the coats of the animals are kept dry. However, the loss of heat in the evaporation of the water from a wet skin, coupled with that by radiation, may be so great that a portion of the food nutrients is burned up merely to keep the animal warm.

Feeding in open yards with no shelter other than windbreaks is common in western sections with little rainfall, even in regions with rigorous winters. In experiments at the Manitoba Experimental Farm[34] steers fattened with no shelter except trees and brush made nearly as large gains as others fed in the barn, providing a convenient supply of water was furnished.

In trials by Potter and Withycombe in eastern Oregon[35] calves and 2-year-olds fed in the open with only a fence and windbreaks for shelter made about as large and economical gains as others having access to an open shed or a barn.

For humid regions with severe winters an open shed should be provided where the animals may find shelter from storms. Where the winters are mild the saving thru providing shelter may not be great enough to warrant the expense. Gray and Ward[36] found in Alabama that steers fattened in the open in winter made practically as large gains as those allowed access to an open shed. Shelter saved only 6 cents per 100 lbs. of gain in the cost of feed.

From his trials Waters at the Missouri Station[37] concludes: "It is of more importance that fattening animals lie down regularly and during a large portion of the time than that they be protected from the cold. Abundance of sunshine and fresh air, a comfortable place in which to lie, and freedom from all external disturbances are ideal conditions for large and economical gains."

Stock cattle being carried over winter are not crowded with heavy rations and hence no great excess of heat is generated in their bodies. The loss of heat by radiation is greater in young animals, for the body surface is larger in proportion to the weight. Yearlings or calves, especially, may hence well be given greater protection than fattening steers, but their quarters should always be well-ventilated. Waters found that yearlings wintered on hay alone or with a small allowance of corn in addition came thru in better condition when housed in an amply ventilated barn and turned out for exercise than when kept in a yard with an open shed. Under usual conditions mature beef breeding cows when in thrifty condition in the fall need no winter shelter other than an open shed.

[34]Ottawa Expt. Farms Rpts. 1910, 1911, 1912.
[35]Ore. Bul. 183.
[36]U. S. Dept. Agr., Bur. Anim. Indus., Bul. 159.
[37]Mo. Bul. 76.

728. Confinement and exercise.—Trials by Day[38] and Grisdale[39] in Canada show that steers fed loose in pens tend to make larger and cheaper gains than if tied in stalls. Not only is there less expense for equipment when this method of feeding is followed, but also less labor is required.

Too much exercise for fattening cattle will make the gains less rapid and more expensive. This is shown in 3 trials by Good at the Kentucky Station[40] in which steers confined in winter to a barn with a covered barnyard were compared with others which had the run of a similar barn and were allowed to range at will on a 20-acre blue grass pasture. Considering the pork produced by the hogs following the steers, the lot confined returned $6.86 more profit per head.

729. Heifers vs. steers.—In the United States the large markets commonly discriminate against heifers, even tho well finished. Steers will usually sell for 50 to 75 cents per cwt. more than open heifers equally well fattened and for about 25 cents more than spayed heifers.[41] In England there is no such discrimination against heifers, but on the contrary a higher price is paid for heifer than for steer beef. Probably the only logical objection to heifers is that they are often pregnant, which lowers the dressing percentage and may affect the value of the carcass. Whatever are the actual merits of the case, beef producers must shape their methods according to the market demands. In experiments by Wilson and Curtiss at the Iowa Station[42] steers were fattened in comparison with both open and spayed heifers. All lots yielded practically the same amount of dressed carcass, and the heifers yielded about 1 per ct. more in the high-priced cuts of meat. However, the steers brought $1.00 per cwt. more in the first trial and $.25 per cwt. more in the second trial than the heifers. But little, if any, benefit was derived from spaying heifers. As a rule, because of the setback caused by the operation of spaying, open heifers make better gains than spayed heifers, if they are fed apart from steers. Therefore, spaying is justified only when heifers must be fed with steers. Then, to keep the animals more quiet in the feed lot, spaying may be profitable.

730. Preparation of feed.—It is pointed out in the following chapter that if hogs follow the steers to get any unmasticated grain, there is usually not enough saving in grinding corn for fattening cattle to justify the expense. On the other hand, all the small grains should be ground or crushed for cattle. In summer corn which is hard and dry may be soaked to render it easier to masticate.

Hay and other dry forage is often chopped or cut for cattle in Europe, where labor is relatively cheap compared with feed. This practice has

[38]Ontario Agr. Col., Rpt. 1907.
[39]Ottawa Expt. Farms, Rpt. 1904.
[40]Information to the authors.
[41]Vaughan, Types and Market Classes of Live Stock, 5th Ed., p. 93.
[42]Iowa Buls. 24, 33.

not been common in this country, however, for roughages have usually not been high enough in price to justify much labor or expense in their preparation. Under present conditions, due to increased freight rates, hay is high priced in sections where the local supply is insufficient to meet the demand, tho in sections of the West where there is a surplus of hay, it is low in price. Chopping or cutting hay for fattening cattle will usually be profitable only if it is relatively high in price. In trials by Potter and Withycombe at the Oregon Station[43] chopping alfalfa hay increased its value 28 per ct. when steers were fed only alfalfa hay. This was because the steers ate more hay, and a smaller proportion was wasted. For steers fed silage and hay or barley and hay, the chopping increased the value of the hay only 7 to 14 per ct. With feeds at war-time prices Gramlich of the Nebraska Station[44] secured greater profit from steers fed a mixture of chopped alfalfa, cracked corn, and cottonseed meal, than from others fed long alfalfa hay, shelled corn, and the same supplement.

From a trial at the Idaho Station,[45] Hickman, Rinehart, and Johnson point out that during rainy seasons hay which is stored in stacks should not be cut unless there is ample shelter available for storing it. Otherwise it will become moldy. Fed alone to steers, alfalfa meal was inferior to good uncut alfalfa hay.

731. The paved feed lot.—In parts of the corn belt the feed lot in winter often becomes a sea of mud and mire. Mumford of the Illinois Station[46] fed one carload of steers during winter in a brick-paved lot and another in an ordinary mud lot, both lots having access to an open shed, the bedding in which was kept dry. Due to this fact the paved-lot steers made no cheaper gains than the others. However, because of their dirty appearance, tho not inferior finish, the mud-lot steers sold for 10 cents less per 100 lbs. Pigs following the paved-lot steers gained 1 lb. more from each bushel of corn fed to the steers than did those following the mud-lot steers. In a trial by Pew, Evvard, and Dunn at the Iowa Station[47] one lot of steers was fed in a paved and another in an unpaved lot, each lot having access to an open shed with a concrete floor. The steers in the paved lot made slightly larger gains and sold for a trifle more per cwt. Due chiefly to the fact that the pigs following the steers in the paved lot were able to recover more corn grain, the gains on this lot were slightly less expensive. The net returns per head from these steers were $4.49 more than for those in the unpaved lot.

[43]Ore. Bul. 174.
[44]Neb. Bul. 174.
[45]Idaho Cir. 18.
[45]Beef Production, p. 155.
[46]Beef Production, p. 155.
[47]Iowa Bul. 182.

CHAPTER XXVII

FEEDS FOR BEEF CATTLE

I. Carbonaceous Concentrates

732. Indian corn.—Of all the concentrates, Indian corn is and will continue to be the great fattening feed for cattle in the United States. It excels not only because of its richness in starch and oil, but also because no other concentrate is so palatable to cattle. (**201-6**) Numerous trials have clearly shown, however, that corn is too low in protein, even for fattening animals, and should therefore be fed with legume hay or else with some protein-rich concentrate, such as linseed meal or cotton-seed meal, when only carbonaceous roughages, such as hay from the grasses or corn or sorghum forage, are used.

The value of legume hay for supplementing corn is shown in the following table, which summarizes the results of 8 trials,[1] averaging 144 days in length, where corn was fed with carbonaceous roughage, such as timothy hay, prairie hay, corn stover or kafir stover, to one lot of 2 or 3-year-old steers, while corn and clover or alfalfa hay were fed to a second lot.

Legume hay as a supplement to corn

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain	
			Concentrates Lbs.	Roughage Lbs.
Lot I, unbalanced ration				
Corn, 15.2 lbs.				
Carbonaceous roughage, 13.0 lbs...	959	1.7	930	832
Lot II, balanced ration				
Corn, 15.4 lbs.				
Legume hay, 13.2 lbs.....	952	2.3	689	575

While the steers in Lot II, fed corn and legume hay, gained 2.3 lbs. per head daily, those in Lot I, getting the unbalanced ration of corn and carbonaceous roughage, gained only 1.7 lbs., and required 35 per ct. more corn and 44 per ct. more roughage for 100 lbs. gain than the others.

The table on the next page shows clearly the importance of adding some protein-rich concentrate to balance the ration, when corn is fed with carbonaceous roughage. This summarizes the results of 4 trials,[2] averaging 132 days, in which one lot of steers was fed only corn and carbon-

[1]Average of 1 trial by Haney (Kan. Bul. 132), 2 by Burtis (Okla. Rpts. 1900, 1901), 1 by Mumford (Ill. Bul. 83), 2 by Skinner and Cochel (Ind. Buls. 115, 129), and 2 by Smith (Nebr. Buls. 90, 93.)

[2]Average of 1 trial by Mumford (Ill. Bul. 83), 1 by Skinner and Cochel (Ind. Bul. 115), and 2 by Smith (Nebr. Buls. 90, 93).

aceous roughage, while linseed meal, cottonseed meal, or gluten feed was added to the ration of the other lot.

Lot I, fed only corn and carbonaceous roughage, gained but 1.6 lbs. per head daily, while Lot II, receiving 2.1 lbs. of protein-rich concentrates in addition, gained 2.2 lbs. per head daily and required about 20 per ct. less feed per 100 lbs. gain. When the corn allowance is properly balanced, not only is the feeding value of this grain greatly increased with both the cattle and the pigs which follow the steers, but it keeps the animals more healthy, shortens the feeding period, and gives a higher finish than can be secured with unbalanced rations.

Protein-rich concentrates as supplements to corn

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Feed for 100 lbs. gain Roughage Lbs.
Lot I, unbalanced ration				
Corn, 16.3 lbs.				
Carbonaceous roughage, 8.3 lbs.....	995	1.6	1,082	522
Lot II, balanced ration				
Corn, 16.7 lbs.				
Protein-rich concentrate, 2.1 lbs.				
Carbonaceous roughage, 8.6 lbs.....	1,002	2.2	862	402

Since the other cereals, such as barley, oats, kafir, and milo, are relatively low in protein, they should be fed with legume hay, just as in the case of corn, or else some protein-rich supplement should be added to balance the ration. However these other cereals, with the exception of rice, are richer in protein than is corn. Therefore a smaller amount of a protein-rich supplement is needed to balance the ration than when corn is fed.

One can readily find how much protein-rich supplement is needed to balance any ration by taking the recommendations of the Morrison feeding standards as a guide. (Appendix Table V.)

733. Adding a protein-rich concentrate to corn and legume hay.—Whether it will pay to add a protein-rich supplement like linseed meal or cottonseed meal to a ration of corn and legume hay for fattening cattle, is a question of much practical importance. Even in the case of clover hay, which is lower in protein than alfalfa, soybean, or cowpea hay, 2-year-old steers given all the hay they will clean up in addition to a full feed of corn will eat enough hay during the early part of the fattening period to balance their ration fairly well. Later, when they eat more corn and less hay, the ration will be lower in protein, and they will usually make more rapid and economical gains if a supplement is added. This is shown in the following table summarizing the results of 3 trials[3] in which 2-year-old steers were fed for periods averaging 172 days:

[3]Skinner and Cochel, 2 trials, Ind. Buls. 129, 136; Mumford, 1 trial, Ill. Bul. 103.

Adding a protein-rich concentrate to corn and clover hay

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.
Lot I, 35 steers				
Corn, 18.4 lbs.*				
Clover hay, 9.4 lbs.....	1,032	2.0	940	484
Lot II, 35 steers				
Corn, 17.7 lbs.*				
Protein-rich concentrate, 2.9 lbs.				
Clover hay, 9.1 lbs.....	1,047	2.4	854	376

*Ear corn fed in the Illinois trial has been reduced to the equivalent of shelled corn.

In each of the trials Lot II, receiving a nitrogenous concentrate (cottonseed meal or linseed and gluten meal) in addition to corn and clover hay, made larger gains and required less feed per 100 lbs. gain. With feeds at the market prices, the gains were also cheaper than in Lot I. Due to better finish the steers in Lot II sold for a higher price in all trials, bringing 25 cents more per 100 lbs. on the average than those in Lot I.

Somewhat larger amounts of the protein-rich supplements were fed in these trials than was necessary to balance the ration. In fact, from what we now know about the nutrient requirements of steers, not over 1.75 lbs. per head daily of cottonseed meal or linseed meal is needed to balance the ration of 2-year-old steers full-fed on corn and clover hay. (**710**) Obviously, more will be needed when corn or sorghum silage is fed in addition, as these feeds are low in protein. When only sufficient cottonseed meal or linseed meal is fed to balance the ration, each 100 lbs. of supplement will usually save 250 to 300 lbs. of shelled corn or the equivalent in corn and other feed. (**750, 776**)

In a recent trial by Peters and Carnes at the Minnesota Station[4] steers fed shelled corn and clover hay made slightly smaller gains than others fed linseed meal in addition, but required no more feed. Consequently the gains were more expensive when the supplement was added. In this trial the steers ate on the average 19.1 lbs. corn per head daily, and 11.6 lbs. clover hay, a larger amount of legume hay than steers will commonly eat when full-fed on corn. Therefore, the ration was better balanced than is usually the case when corn and clover hay are fed alone.

That alfalfa hay is rich enough in protein to fully balance corn for yearlings or 2-year-old steers full-fed corn and alfalfa hay, is shown in trials by Gramlich at the Nebraska Station.[5] On the average, steers fed alfalfa hay, shelled corn, and either linseed meal or cottonseed cake made no more rapid gains, required no less feed for 100 lbs. gain, and sold for no higher a price than did steers fed merely corn and alfalfa hay. The steers fed alfalfa hay ate on the average 16.6 lbs. corn and 10.9 lbs. hay per head daily and gained 2.41 lbs. For each 100 lbs. gain there were required 695 lbs. corn and 460 lbs. alfalfa hay.

[4]Information to the authors. [5]Nebr. Bul. 174; information to the authors.

Fattening calves require a larger proportion of protein in their ration, and therefore it may be advisable to add 1 to 1.5 lbs. of linseed meal, cottonseed meal, or other protein-rich supplement to a ration of corn and alfalfa hay. For example, in a trial at the Kansas Station,[6] Cochel found that calves fattened on a ration of shelled corn, linseed meal, and alfalfa hay made slightly larger and more economical gains and returned $1.76 more profit per head than others fed only corn and alfalfa hay.

734. Amount of corn to feed fattening steers.—Whether to feed fattening cattle all the corn or other concentrates they will eat, or to limit the amount of concentrates, or perhaps even fatten them on only silage, hay, and enough protein-rich supplement to balance the ration is a problem of the utmost importance in fattening cattle. Upon good judgment in deciding this question may largely depend the financial outcome of the feeding operations. This matter has been fully discussed in the preceding chapters. (**715-6**) It has there been pointed out that the two most important factors to consider in deciding how much concentrates to feed are: (1) The relative price of concentrates and roughages; (2) The probable difference in selling price for cattle thoroly finished on a liberal allowance of concentrates and for those only fairly well fleshed. The same principles apply when barley, grain sorghum, or other cereals are used in place of corn.

735. Preparation of corn for beef cattle.—The practice of successful stockmen in the corn belt and the results of trials at the experiment stations agree in showing that, in general, getting corn to cattle in the simplest manner and with the least preparation and handling is the most economical, when pigs follow the steers to consume any grains which escape mastication. The majority of feeders accordingly feed shock corn, husked or unhusked ear corn, or shelled corn, but few using corn meal or corn-and-cob meal thruout the fattening period. To induce young animals to eat sufficient corn to overcome their tendency to grow rather than to fatten, more preparation is warranted than for older ones. Many skilled feeders seek to "keep the feed better than the cattle;" i.e., they prepare the feed more as the cattle gain in flesh. Thus, they may start the steers on shock corn; then as they require more concentrates, add snapped corn or ear corn; still later the ear corn is broken or shelled; and toward the close of the fattening period, to tempt them to consume a heavier allowance of grain, corn meal or corn-and-cob meal is employed.

Corn long stored in the crib becomes dry and hard, losing fragrance and aroma thru exposure to air and vermin. For summer feeding such grain should be specially prepared by soaking or shelling, or possibly by grinding. Corn should be soaked from 12 to 18 hours, care being taken to change the water frequently and to keep the feed boxes clean and sweet.

[6]Information to the authors.

736. Feeding corn in various forms.—Broken ear corn proved the most profitable manner of feeding corn to 2-year-old steers with pigs following, in 3 trials by Allison at the Missouri Station.[7] Shelled corn ranked second, ground corn third, coarsely crushed corn and cob fourth, and corn-and-cob meal last. The steers fed ground corn made the most rapid gains, on the average, but for combined profit from steers and hogs, ground corn was excelled by ear corn and shelled corn.

Similarly, in a trial by Mumford at the Illinois Station[8] ear corn proved the most profitable. Steers fed shock corn at first and later changed to ear corn, ranked second. Below these in economy came corn meal, corn-and-cob meal, and shelled corn. Likewise in a trial by Gramlich at the Nebraska Station[9] snapped ear corn proved more profitable than shelled corn.

In a trial by Good and Horlacher at the Kentucky Station[10] in which either shelled corn or broken ear corn was fed with corn silage, straw, and cottonseed meal to 2-year-old steers, the broken ear corn was the more economical.

For calves fed for baby beef there may be some advantage in grinding corn, tho the saving is not large. In one trial at the Kansas Station[11] Cochel found a slight profit in grinding corn for beef calves fed corn, linseed meal, alfalfa hay and silage, but in another similar trial there was no saving.

If hogs do not follow fattening cattle, corn should always be ground. As is pointed out in a later chapter, the number of hogs needed to consume the corn not utilized by the cattle will depend on the method of preparation. (804)

737. Soft corn.—Soft corn, containing 35 per ct. of moisture at the beginning of the trial and 16 per ct. at its close, produced rather more economical gains, in a trial by Kennedy and Rutherford at the Iowa Station[12] than did mature corn, taking dry matter as the basis of comparison. The cattle finished as well on the soft corn as on the mature corn. (205)

738. Barley.—In sections of the western and northern states where corn does not thrive, barley is of much importance as a grain for fattening cattle. (226) The gains of cattle full-fed ground barley will usually be as rapid as tho fed corn, but in some instances slightly more feed may be required for 100 lbs. gain, due to the fact that barley is higher in fiber than is corn. Barley should always be crushed or ground for cattle.

In a trial with calves fed for baby beef by Cochel at the Kansas Station[13] ground barley not only produced more rapid gains than shelled corn, but was worth fully as much per ton. Likewise in a trial by Fuller, Morrison, and Fargo at the Wisconsin Station[14] with 2-year-old steers,

[7]Mo. Bul. 149.
[8]Ill. Bul. 103.
[9]Nebr. Bul. 174.
[10]Ky. Cir. 26.
[11]Information to the authors.
[12]Iowa Bul. 75.
[13]Information to the authors.
[14]Wis. Bul. 323, pp. 12-13.

similar results were secured. In two trials by Wilson at the South Dakota Station[15] and in a trial by Haney at the Hays, Kansas, Branch Station,[16] steers fed ground barley made slightly less rapid gains than others fed corn, but required no more feed for 100 lbs. gain.

Steers fed barley and alfalfa hay in a trial by Martin and Leiper at the Colorado Station[17] made nearly as rapid gains as others fed corn and alfalfa, and barley proved to be worth only 5 per ct. less than corn per ton. Similar results were secured in a trial by Foster and Simpson at the New Mexico Station[18] with steers fed ground corn or ground barley with alfalfa hay and a small allowance of cottonseed meal. In this trial ground barley was worth only 4 per ct. less per ton than ground corn per ton.

In only one trial has considerably more feed been required for 100 lbs. gain on barley than on corn. This was in a recent comparison by Peters and Carnes at the Minnesota Station[19] in which ground barley was worth about 22 per ct. less than shelled corn per ton, taking into consideration the greater feed requirement for 100 lbs. gain on barley and also the smaller amount of pork produced by the hogs following the steers fed barley.

739. Wheat.—This grain is seldom fed to cattle except when off grade or unusually low in price. As wheat is less palatable than corn, steers may not eat so much and hence they may make slightly smaller gains. Otherwise, the feeding value of wheat is as high as that of corn or barley.[20] (**215**) It should be crushed or ground for cattle.

Low-grade, shrunken wheat is usually richer in protein than plump wheat and seems to tend to produce growth rather than to fatten cattle, according to results secured at the North Dakota Station[21] in a trial by Shepperd and Richards.

740. Oats.—Since oats are usually high in price compared with other grains, they are seldom used as the chief concentrate for fattening, tho they are well liked by cattle and produce beef of good quality. (**223**) Oats tend to cause growth in cattle rather than to fatten them rapidly, because they are much bulkier and higher in fiber than corn or barley, and also richer in protein than corn. Hence they are more widely used for growing cattle than during fattening. They are also useful for mixing with corn in starting cattle on feed, especially calves being fed for baby beef. (**819**) For cattle, oats should be ground or crushed, as any whole grains escaping mastication are not so readily recovered by pigs as are the grains of corn.

[15]S. D. Bul. 160.
[16]Kan. Bul. 128.
[17]Colo. Station, Information Bul., Jan. 1918.
[18]N. Mex. Bul. 101.
[19]Information to the authors.
[20]Haney, Kan. Bul. 128; Linfield, Mont. Bul. 58; Burnett and Smith, Nebr. Bul. 75.
[21]N. D. Bul. 73.

Heavy, plump oats have given good results when fed as the only concentrate to fattening cattle. In trials by Wilson at the South Dakota Station[22] ground oats fed with corn silage and a small amount of linseed meal produced nearly as large gains as ground corn. On the average the oat-fed steers required 862 lbs. concentrates and 746 lbs. silage for 100 lbs. gain, while the corn-fed steers required 856 lbs. concentrates and only 648 lbs. silage. Linfield at the Montana Station[23] found ground oats, crushed wheat, and ground barley about equally valuable when fed with clover hay to fattening steers.

741. Kafir.—The grain sorghums are of great and increasing importance for beef production thruout the southern portion of the Great Plains region. As the following paragraphs show, they produce practically as rapid gains as does corn, and closely approach that grain in feeding value per pound. (**235-40**) The grain sorghums are relatively low in protein and should therefore be fed with legume hay, or else a supplement should be added to the ration. The following table presents the results of 3 trials,[24] averaging 138 days, in which ground kafir and alfalfa hay were fed to one lot of steers, and ground corn and alfalfa hay to another lot.

Kafir vs. corn for fattening steers

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Roughage Lbs.
Lot I, total of 18 steers				
Ground kafir, 16.7 lbs. Alfalfa hay, 15.1 lbs	952	2.4	697	636
Lot II, total of 18 steers				
Ground corn, 15.5 lbs. Alfalfa hay, 15.2 lbs	943	2.5	612	610

The steers fed kafir made nearly as large gains as those fed corn, but required somewhat more feed for 100 lbs. gain. With feeds at normal prices, in these trials kafir was worth about 14 per ct. less per ton than corn. In trials by Cochel at the Kansas Station[25] and by Foster and Simpson at the New Mexico Station[26] practically the same results were secured. Even larger gains were made with kafir chop than with corn chop in a trial by Burns at the Texas Station[27] and less feed was required for 100 lbs. gain. Ground entire kafir heads at $16 a ton proved slightly less economical than ground kafir grain at $20 a ton in a trial by Cochel at the Kansas Station.[28] (**237**)

742. Milo; feterita.—As yet but few trials have been carried on to find the relative value of the different grain sorghums for fattening

[22]S. D. Bul. 160.

[23]Mont. Bul. 58.

[24]Average of 2 trials by Burtis (Okla. Rpts. 1899, 1900, 1901) and 1 by Haney (Kan. Bul. 132).

[25]Information to the authors.

[26]N. Mex. Bul. 101.

[27]Tex. Bul. 110.

[28]Information to the authors.

cattle, but probably their actual value does not differ widely. In a trial by Burns at the Texas Station[29] with 2-year-old steers milo chop proved equal to corn chop in rate and economy of gain, and in a trial with calves fed for baby beef by Jones at the Spur, Texas, Branch Station[30] ground feterita heads were fully equal per ton to ground ear corn, including husks. In this trial ground milo heads were not of quite as high value as ground feterita heads. (238-9)

743. Emmer.—For the northern part of the Great Plains region emmer ranks high as a grain for fattening cattle. (233) Altho in 2 trials by Wilson at the South Dakota Station[31] it proved fully equal to corn, its usual value will probably be slightly lower than that of corn, because it resembles oats in composition and is much higher than corn in fiber. It should be an excellent concentrate to use in starting cattle on feed. (740) Fed to calves fattened for baby beef at the South Dakota Station,[32] emmer produced a hard fat the same as did oats, and the meat was of as good quality as that from corn. Emmer should be crushed or ground for cattle.

744. Millet.—The seed of hog or broom-corn millet, which is a reliable grain crop on the northern plains, is a satisfactory feed for fattening cattle. (243) In a trial by Wilson and Skinner at the South Dakota Station[33] calves fattened for baby beef on ground hog millet seed and clover hay gained 1.5 lbs. per head daily, while others fed corn and clover hay gained 1.8 lbs. The millet was worth about three-fourths as much, pound for pound, as corn. It produced carcasses of as good quality as did corn, but with somewhat softer fat.

745. Rough rice and rice by-products.—In the South low-grade rough rice, unsuited for human consumption, and also rice bran, a by-product of the rice mills, are often economical feeds for cattle. (234) In a trial by Burns at the Texas Station[34] rice bran was worth 14 per ct. more a ton than ground milo heads, fed with silage and cottonseed meal, tho it was less palatable than the milo. In trials by Craig and Marshall, also at the Texas Station,[35] rice polish was about equal to cottonseed meal, and 10 lbs. of rice bran were equal to 6 lbs. of cottonseed meal when forming 40 per ct. of the concentrates. Rice hulls proved to be without value. Red rice, a pest in the rice fields, is satisfactory for fattening cattle, when ground.[36]

746. Sugar-beet pulp; beet tops.—In the vicinity of the western beet sugar factories thousands of cattle are fattened annually on beet pulp with alfalfa hay, which admirably supplements this feed, that is low in both protein and lime. A limited allowance of grain is also usually fed in addition. Often the steers are fed a limited allowance of beet molasses,

[29]Tex. Bul. 110.
[30]Am. Soc. Anim. Prod., Proceedings, 1921, pp. 16-21.
[31]S. D. Bul. 160.
[32]S. D. Bul. 97.
[33]S. D. Bul. 97.
[34]Tex. Bul. 182.
[35]Tex. Buls. 76, 86.
[36]Cruse, Tex. Bul. 135.

another by-product of the beet sugar factories. Animals should be accustomed gradually to the pulp, later getting all they will clean up. Care should be taken that refuse pulp does not accumulate in the troughs and decompose. (**275**)

Wet beet pulp was compared with corn silage in trials during 4 years at the Colorado Station[37] by Morton and colleagues. Each year one lot of 2-year-old steers was fed wet beet pulp, alfalfa hay, and a limited amount of beet molasses and cottonseed cake, while the other lot received corn silage instead of the pulp. The results of the trials are summarized in the following table:

Wet beet pulp vs. corn silage for fattening steers

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain		
		Concentrates Lbs.	Pulp or silage Lbs.	Alfalfa hay Lbs.
Lot I, fed beet pulp				
Beet pulp, 78.8 lbs. Molasses, 4.0 lbs. Hay, 10.4 lbs. Cottonseed cake, 2.7 lbs.	2.43	274	3,334	425
Lot II, fed corn silage				
Silage, 33.3 lbs. Molasses, 4.0 lbs. Hay, 8.9 lbs. Cottonseed cake, 2.7 lbs..	2.08	322	1,590	425

In each trial the steers fed the wet beet pulp gained more rapidly than those fed corn silage, and they sold on the average for 43 cents more per cwt. In producing gains, 1 ton of wet beet pulp, as fed, was equal to 953 lbs. corn silage and 29 lbs. concentrates. Taking into consideration the losses in hauling pulp and the waste due to spoilage, the conclusion was reached that it was not worth over 40 per ct. as much per ton as corn silage.

In another trial at the Colorado Station[38] steers fed wet beet pulp and alfalfa hay, with 6.6 lbs. corn per head daily in addition gained 2.6 lbs., while others fed alfalfa hay and corn gained only 1.8 lbs. and steers fed wet pulp and hay, without any corn, also gained 1.8 lbs. In this trial 1 ton of pulp replaced 575 lbs. alfalfa hay and 70 lbs. corn.

It has been pointed out in Chapter XI that cattle may be turned on the beet fields to graze on the beet tops after the removal of the beets, or the beet tops may be ensiled and fed in place of other silage. (**279**) In trials at the Colorado Station[39] pasturing the tops proved more economical under favorable weather conditions than ensiling them. The average value of an acre of beet tops, compared with alfalfa hay at $7 a ton and corn silage at $4 a ton, was $6.95 an acre in two autumns when the weather was good. When the weather is bad, much of the feeding value is lost thru the tops being tramped into the mud and thru decay. Steers fed a limited amount of beet top silage along with other feeds

[37]Colo Station, Information Bul., Jan. 1918, and information to the authors.

[38]Carlyle and Griffith, Colo. Bul. 102.

[39]Morton and Maynard, information to the authors; also *Thru the Leaves*, Sept. 1921.

made fair gains, but not so large as those fed wet beet pulp or corn silage. No other beet by-products should be fed with beet top silage, as there might be a tendency toward scouring the cattle. In trials during two years, when limited amounts of beet top silage were fed it was worth on the average only $2.39 a ton compared with corn silage at $4.00 a ton.

747. Dried beet pulp.—Most of the dried beet pulp produced is fed to dairy cows, but it may also be used for fattening cattle. (**276**) However, it is a bulky feed and tends to produce growth rather than to fatten if used as the only concentrate.[40] In a trial at the Colorado Station[41] 100 lbs. of dry matter in dried molasses beet pulp did not prove as valuable for fattening steers as the same amount of dry matter in a combination of wet beet pulp and beet molasses.

748. Molasses; molasses feeds.—In the sugar-cane districts of the South, *cane* or *blackstrap molasses* is quite commonly an economical feed for fattening cattle, as it is usually considerably lower in price per ton than corn or other grains. It should be used to replace not more than about half the concentrates ordinarily fed and should be diluted and poured over silage or over hay or other dry roughage. This will induce the steers to consume more roughage than they otherwise would. (**280**)

In a 120-day trial at the Texas Station[42] Burns fed one lot of 2-year-old steers a ration of 15.1 lbs. corn, 3 lbs. cottonseed meal, and 12.6 lbs. cottonseed hulls, while another lot was fed 6.5 lbs. cane molasses in place of the same weight of corn. The steers fed molasses made slightly larger gains and required a little less feed for 100 lbs. gain. In one trial by Evvard and Culbertson at the Iowa Station,[43] adding 5 lbs. cane molasses per head daily to a ration of shelled corn, linseed meal, corn silage and legume hay increased the rate of gain and the molasses proved to be worth 23 per ct. more per ton than shelled corn. On the other hand in a similar trial the following year, the steers fed molasses made smaller gains, and molasses was worth decidedly less than corn per ton when fed at this rate of 5 lbs. per head daily. Likewise in one trial at the Pennsylvania Station[44] by Tomhave and Severson, adding 5 lbs. of molasses to a ration of corn, mixed hay, corn silage and cottonseed meal did not increase the gains and the molasses was worth less per ton than corn, while in a later trial by Tomhave, MacKenzie, and Bentley molasses was worth more per ton than shelled corn when 3.7 lbs. was added to a similar ration. In a trial by McCampbell and Winchester at the Kansas Station[45] 2 lots of steers were fed for 75 days on a ration of cane silage, alfalfa hay, and 2.26 lbs. linseed meal to balance the ration. Then shelled corn was added to the ration of one lot and 5 lbs. cane molasses per head daily to that of the other lot for a 45-day finishing period. The steers fed corn made slightly more rapid gains, but the financial outcome was a little the best from

[40] Shaw and Norton, Mich. Bul. 247.
[41] Morton and Maynard, information to the authors.
[42] Tex. Bul. 110.
[43] Information to the authors.
[44] Information to the authors.
[45] Kan. Cir. 86.

those fed molasses, due to the fact that at that time the price of corn was over one-fourth more than that of molasses per ton. From these trials we may conclude that it is usually not profitable to feed as heavy an allowance of molasses as 5 to 6 lbs. unless it can be secured considerably below the price of corn on the farm.

Even when molasses is as high or even higher in price than corn, the use of 1 to 3 lbs. per head daily, diluted and poured over the silage or other roughage, may be economical, in order to induce the cattle to eat more roughage. In 2 trials by Skinner and King at the Indiana Station[46] and in a trial by Evvard and Culbertson at the Iowa Station,[47] feeding 2 to 3 lbs. of molasses per head daily on the corn silage increased the gain slightly compared with steers fed corn silage, clover hay, corn and linseed or cottonseed meal. The molasses produced a slightly better finish on the steers and in each trial was worth more per ton than shelled corn.

The use of *beet molasses* is greatly increasing in the beet-sugar districts. (277) It is spread over hay or cut straw, either undiluted or thinned with water. Owing to its laxative effect, not more than 4 to 8 lbs. of beet molasses should be fed per head daily to fattening cattle. When fed in limited amounts beet molasses is worth about as much as cane molasses for fattening cattle. In the trials previously referred to at the Iowa Station beet and cane molasses were compared, various allowances up to 5 lbs. per head daily being fed. One year the results were slightly in favor of cane molasses but the next year the reverse was true.

Molasses feeds of many different brands are now on the market, many being especially compounded for fattening cattle. (281) In trials at the Indiana, Iowa, and Nebraska Stations[48] various brands of proprietary molasses feeds have been compared with the standard and highly satisfactory corn belt ration consisting of shelled corn, corn silage, legume hay, and enough linseed or cottonseed meal to balance it. The results of these trials all agree in showing that while the better grades of these feeds are satisfactory for fattening cattle, when molasses feeds are substituted for corn, the gain is decreased rather than increased, and also more feed is required for 100 lbs. gain. In sections where corn is high in price compared with such feeds, they may be very economical, but in these trials at corn-belt stations the profit was greater without the molasses feeds, except in one trial at the Nebraska Station conducted in 1919, when corn was considerably higher in price than the molasses feed. Molasses feeds are often unwisely fed in place of a protein-rich supplement like linseed or cottonseed meal.

749. Hominy feed.—This corn by-product is fed much less commonly to fattening cattle than it is to dairy cows, but it is an entirely satisfac-

[46]Ind. Buls. 183, 191.

[47]Information to the authors.

[48]Evvard and Culbertson, 2 trials, Iowa Station, information to the authors; Skinner and King, 2 trials, Ind. Buls. 183, 191; Gramlich, Nebraska Station, 2 trials, information to the authors.

tory concentrate for beef cattle. Its feeding value per ton is no greater than that of corn. (**213**) In a trial with beef calves being fattened for baby beef at the Kansas Station,[49] Cochel found ground corn slightly superior to hominy feed. Likewise in one trial by Gramlich at the Nebraska Station similar results were secured in a comparison of shelled corn and hominy feed for 2-year-old steers, but in another trial the hominy feed was of slightly higher value than corn.[50]

II. Nitrogenous Concentrates

750. Cottonseed meal.—This protein-rich concentrate is the basis of the fattening of beef cattle in the South and is widely used in the northern states as a supplement to rations deficient in protein. (**249-50**) Trials at the Indiana Station, which are reviewed later (**777**), show that 2.5 lbs. of cottonseed meal per head daily per 1,000 lbs. live weight is sufficient to balance a ration of shelled corn, corn silage, and oat straw or clover hay. Therefore in the North it is not economical to feed more than this to fattening cattle, for in this section cottonseed meal is practically always higher in price than corn or other grains.

When cottonseed meal or linseed meal is added to a ration deficient in protein and only sufficient is fed to balance the ration, each 100 lbs. of these supplements will usually save the equivalent of 250 to 300 lbs. of shelled corn, due to the fact that considerably less feed will be required per 100 lbs. gain. In addition there will be an important added advantage, due to the fact that the steers fed the properly-balanced ration will reach a better finish and sell for a higher price on the market. (**733, 776**)

In the South, cottonseed meal is quite commonly the cheapest concentrate available, and it is then fed as the only concentrate, along with cottonseed hulls, corn silage, or other roughage. Since the meal is poisonous to cattle when fed in excess, several trials have been carried on by the southern stations to find how large an allowance should be fed for the best results. In all cases cattle should be accustomed to cottonseed meal gradually and it should be mixed with roughage so a greedy steer can not overeat.

During each of 3 years Willson fed 2-year-old steers, averaging 944 lbs. in weight, for 90-day periods at the Tennessee Station[51] on corn silage and different amounts of cottonseed meal, as is shown in the table. The steers fed low cottonseed meal allowances received 3 lbs. of meal for the first 30 days, 4 lbs. for the second 30 days, and 5 lbs. for the last month. Those on medium allowances received 4 or 5 lbs. for the first month, 5 or 6 for the second, and 6 or 7 for the third; while those on the heavy allowances received 7, 8, and 9 lbs. respectively, for the 3 months of the feeding period.

[49]Information to the authors. [50]Information to the authors. [51]Tenn. Bul. 104.

Low, medium, and heavy allowances of cottonseed meal

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Meal Lbs.	Silage Lbs.	Cost of 100 lbs. gain* Dollars
Low allowance, total of 32 steers				
Cottonseed meal, 4 lbs. Corn silage, 56 lbs...	1.62	253	3,542	8.47
Medium allowance, total of 24 steers				
Cottonseed meal, 6 lbs. Corn silage, 52 lbs...	1.70	335	3,124	8.87
Heavy allowance, total of 24 steers				
Cottonseed meal, 8 lbs. Corn silage, 50 lbs...	1.66	491	3,622	11.56

*Cottonseed meal at $25 and corn silage at $3 per ton.

In none of the trials did the heavy allowance of cottonseed meal produce larger gains than the medium allowance. On the average the medium allowance made slightly larger but more expensive gains than the low allowance. Willson concludes that the use of as much as 7 to 9 lbs. of cottonseed meal per head daily is uneconomical except for short feeding periods of only 30 to 50 days.

Since the feeders of the south Atlantic states have access to the large eastern markets, which demand well-finished cattle, Gray and Curtis conducted trials at the North Carolina Station[52] to determine the maximum amount of cottonseed meal which could be fed with good results to 2-year-old steers with corn silage or cottonseed hulls given in unlimited amount. In these trials the conclusion was reached that cattle fed 7.5 lbs. of meal per head daily with either silage or hulls will continue to gain and finish quite satisfactorily for 130 to 140 days, which is the maximum period for feeding this allowance with hulls. With corn silage the feeding period may be extended 30 to 50 days or even somewhat longer without harm. When 9 to 10.5 lbs. of meal is fed with hulls, the daily gains decrease after 120 to 130 days until finally the animal begins losing weight. The same amount of meal may be fed with silage for 30 to 60 days longer with continuous gains and consequent high finish. The retarding of the poisonous effect of cottonseed meal by silage seems to be due to the succulent nature of the silage, for the same effect is also produced by pasturage.

Feeding as large amounts of cottonseed meal as here indicated is advisable only when the market pays a sufficient premium for a thoroly fattened steer over one carrying only moderate finish. Whether to feed cottonseed meal as the only concentrate or to use in addition corn or other grain, will depend on the prices of the feeds. If the other feeds cost more per ton than cottonseed meal, adding them will usually make the gains more expensive.[53]

Cottonseed meal is very poisonous to young calves and should therefore not be fed to them, except possibly as only a small part of a suitable concentrate mixture. After calves are 3 to 4 months old a limited amount of cottonseed meal may be fed with safety. Not over 0.5 to 1.5 lbs. per

[52]N. C. Buls. 218, 222, and information to the authors.

[53]Ward, Curtis, and Peden, U. S. D. A. Bul. 628; Ward, Jerdan, and Lloyd, U. S. D. A. Buls. 631, 761.

head daily should be fed at one year of age, except to calves being fattened for the market as baby beef.[54] Ward reports that in several trials beef calves ranging from 7 to 10 months in age when placed on feed have been fed 3 to 4 lbs. of cottonseed meal per head daily for periods of 100 to 112 days.[55] Longer feeding with these amounts of meal would undoubtedly have poisoned the calves.

Ward, Gray, and Jerdan[56] carried on trials during 6 years to determine whether it was more profitable in the southeastern states to fatten calves for baby beef on cottonseed meal as the only concentrate or to substitute corn for a part of the cottonseed meal. They found that where corn was fed liberally the calves made larger gains than when cottonseed meal was the only concentrate. However, the addition of corn invariably increased the cost of the gains, and the calves fed cottonseed meal without any corn usually returned a slightly greater profit.

751. Cold-pressed cottonseed cake; cottonseed feed.—*Cold-pressed cottonseed cake* or *meal* is well liked by cattle and produces very satisfactory results. (**248**) As it contains the hulls and is thus much lower in protein and higher in fiber than cottonseed meal, it is worth correspondingly less per ton. Averaging the results of 3 different trials,[57] it has required 138 lbs. of cold-pressed cottonseed cake or meal to equal 100 lbs. of choice cottonseed meal. In each trial the value of the cold-pressed cake or meal was slightly higher compared with the cottonseed meal than its protein content would indicate. A safe basis for valuing cold-pressed cottonseed cake or meal in comparison with cottonseed meal when the guaranteed crude protein content of each is known, is to estimate the amount of cottonseed meal and of cottonseed hulls a ton of the cold-pressed product contains, and add to the value of the meal the value of the hulls as roughage.

Cottonseed feed, a mixture of cottonseed meal and hulls, was compared with cottonseed meal as a protein-rich supplement in a trial by Tomhave at the Pennsylvania Station.[58] Due to the lower protein content of the cottonseed feed, considerably more was needed to balance the ration than of cottonseed meal. Cottonseed meal at $65.00 per ton was a decidedly more economical feed than cottonseed feed at $52.50 per ton. Rarely is cottonseed feed economical for northern farmers. (**247**)

752. Cotton seed.—While whole cotton seed was once commonly fed to beef cattle in the South, but little is now used, both because of the value of the seed for oil production and because cottonseed meal gives uniformly better results than the whole seed. (**245**) For instance, in a trial by Burns at the Texas Station[59] cottonseed meal was cheaper at $26

[54]Sheets and Thompson, U. S. D. A. Farmers' Bul. 1179.

[55]Ward, U. S. D. A. Farmers' Bul. 655.

[56]U. S. D. A. Bul. 631; Ala. Bul. 158.

[57]Iowa Station, Kennedy and Robbins, Breeder's Gaz. 58, 1910, p. 303; Burns, Texas Bul. 198; Ward, Jerdan, and Lloyd, U. S. D. A. Bul. 761.

[58]Information to the authors. [59]Tex. Buls. 110, 159.

per ton than cotton seed at $12 per ton. In a later trial Burns found that when the allowance of cotton seed was increased beyond 8 lbs. per head daily the animals scoured badly, probably due to the large amount of oil in the seed. On substituting cottonseed meal for the cotton seed they recovered and made much larger gains. In a trial at the Arizona Station,[60] Stanley found that it required 170 lbs. of cotton seed to equal 100 lbs. of low-grade cottonseed meal containing only 33.6 per ct. of crude protein.

753. Linseed meal.—Thruout the northern states linseed meal is widely used as a protein-rich supplement for beef cattle. (**254**) While it is lower in protein than cottonseed meal, trials at various stations show that it is worth fully as much or more per ton than choice cottonseed meal for fattening cattle. This is doubtless due to its well-known beneficial regulating effect on the system.

In two trials by Allison at the Missouri Station[61] in which equal amounts of linseed meal and cottonseed meal were fed with shelled corn, corn silage and alfalfa hay or with corn silage and alfalfa hay, without corn, the gains were slightly larger, except in one case, on linseed meal. Also more pork was produced by the pigs following these steers. The steers fed linseed meal sold at a slightly higher price per cwt. and with both supplements at the same price per ton, the net return over cost of feed was $5.52 per steer more for those fed linseed meal. In 3 trials by Tomhave and Bentley at the Pennsylvania Station[62] steers fed linseed meal with corn silage and shredded corn stover for roughage, and with or without corn grain in addition, made slightly larger gains on the average than steers fed cottonseed meal with the same roughages. With linseed and cottonseed meal at the same price per ton, the profit per steer was slightly greater for those fed linseed meal. Linseed meal was likewise found slightly superior to cottonseed meal in trials by Smith at the Nebraska Station.[63] In one trial by Cochel at the Kansas Station[64] with calves fed for baby beef, linseed meal was slightly more profitable than cottonseed meal at the same price per ton, and in another trial the results were reversed. On the average, linseed meal was worth a little more than cottonseed meal.

754. Soybeans; soybean oil meal.—The protein-rich seed of the *soybean* is well suited to serve as a nitrogenous supplement for fattening cattle. In trials by Skinner and King at the Indiana Station[65] ground soybeans gave good returns when 2.5 to 3.0 lbs. were fed per head daily to supplement a ration of shelled corn, corn silage, and oat straw or clover hay. Doubtless due to the high oil content of the soybeans, they had rather too laxative an effect on the steers. Also, after the cattle had been on feed for 90 to 100 days, they seemed to tire of the soybeans, probably again due to the richness in oil. During the time when the

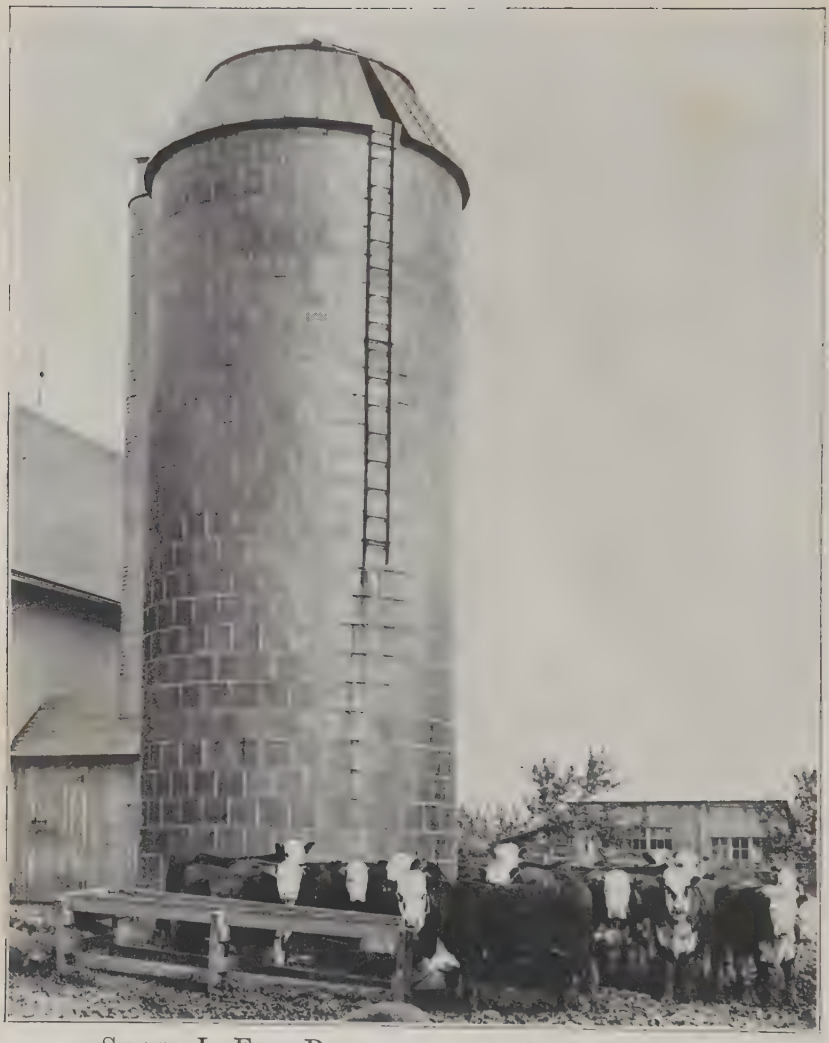
[60] Ariz. Bul. 93.
[61] Mo. Bul. 150.
[62] Information to the authors.
[63] Nebr. Bul. 100.
[64] Information to the authors.
[65] Ind. Buls. 167, 178, 183, 237.

CORN EXCELS AS A FATTENING FEED FOR CATTLE

Corn is unexcelled as a grain for fattening cattle on account of its richness in starch and oil. Furthermore, no other concentrate is as palatable to fattening cattle as is corn.

FATTENING STEERS ON BEET PULP IN THE WEST

In the vicinity of the beet sugar factories thousands of cattle are fattened on wet beet pulp and other feeds. In the feed lots shown in this view the beet pulp is brought from the beet sugar factory on the tramway.



SILAGE IS FAST REVOLUTIONIZING BEEF MAKING

Wherever corn or the sorghums thrive, silage from these crops has proved of great value in cheapening the cost of beef production.

beans were relished by the steers, they proved fully equal to cottonseed meal, but after this they were less efficient. (256)

Soybean oil meal is an excellent protein-rich supplement for cattle, being considerably richer in protein than linseed meal or soybeans, and having no tendency to throw the animals off feed, for most of the oil has been removed. In a trial by Hostetler at the North Carolina Station[66] soybean oil meal proved slightly superior to cottonseed meal when fed with corn silage and corn stover. (257)

755. Soybeans, cowpeas, and corn.—In the southern states it is possible to grow a winter crop of small grain and harvest it in time to plant soybeans, cowpeas, or corn, thus securing 2 crops each year from the same land. During 7 years various crops have been grown on different acres at the Tennessee Station[67] by Willson and fed to steers, to determine the amount of beef produced per acre under the different systems of cropping. In addition to the product from the given acre, the steers were each fed 20 lbs. of corn silage per head daily. The manure resulting from the crops on each acre was returned thereto.

Of the various combination crops, an acre on which soybeans were grown for grain and stover, with barley as a winter grain crop, produced the largest amount of beef per acre, 508 lbs. per acre. Cowpeas yielded much less grain and stover and produced less beef per acre. An acre on which were grown corn for grain and stover, with barley as the winter crop, made considerably less beef per acre than the soybean acre, due in no small measure to the unbalanced nature of the ration of corn grain, corn stover, corn silage, and barley grain. Alfalfa, tested for 5 years, slightly surpassed even soybeans. The returns from these acres well illustrate the possibilities of the South for beef production in a system whereby more than a single crop is grown each year. (262)

756. Wheat bran.—This bulky feed, which is only fairly rich in protein, is often used mixed with corn or other grain in starting cattle on feed. In some districts it is commonly used as the supplement for fattening cattle thruout the feeding period. Because it is much lower in protein than linseed meal or cottonseed meal, much more must be fed to balance the ration. Due to the bulky nature of bran and its low energy value, steers make less rapid gains and do not reach as high a finish when bran is fed as when linseed or cottonseed meal is used as the supplement. Therefore, if bran is fed at the beginning of the fattening period, it is usually best to replace it with a richer supplement when the steers are on full feed. (218)

In 3 trials at the Pennsylvania Station[68] by Tomhave, Severson, and Gerlaugh, the common Pennsylvania ration of wheat bran, corn, mixed hay and corn stover proved decidedly inferior to one of corn, cottonseed meal, mixed hay, and corn silage, undoubtedly due in large part to the substitution of silage for the stover. Wheat bran at $25.00 a ton was

[66]N. C. Exten. Farm News, 4, 1918, No. 23.
[67]Tenn. Bul. 114.
[68]Penn. Buls. 133, 145.

not so economical a source of protein as cottonseed meal at $32.66 a ton, or alfalfa hay at $15.00 a ton. In 4 trials at the Nebraska Station[69] Smith found that when fed as a supplement to corn and prairie hay, corn stover, or corn silage, bran produced somewhat smaller gains than linseed meal, cottonseed meal, or cold-pressed cottonseed cake and the gains were more expensive.

757. Gluten feed.—Tho most commonly fed to dairy cows, gluten feed is a satisfactory nitrogenous concentrate for fattening cattle. (**210**) In trials at the Missouri Station[70] in which the value of various supplements to corn for steers of various ages on good bluegrass pasture was compared, Mumford found that steers fed linseed or cottonseed meal and corn generally made slightly larger gains than others fed gluten feed and corn. In trials by Evvard, Dunn, and Savin at the Iowa Station[71] in which gluten feed was fed to 2-year-old steers as a supplement, combined with a small amount of linseed meal, satisfactory gains were made but there was less profit than when linseed meal was used as the only supplement.

758. Dried distillers' grains; distillery slop.—Tho dried distillers' grains have been fed most commonly to dairy cows they may be used satisfactorily as a protein-rich supplement for fattening cattle, if they are cheaper sources of protein than linseed or cottonseed meal. (**283**)

Before the advent of national prohibition many cattle were fattened on the wet distillery slop or mash in the vicinity of distilleries. In such feeding the slop is pumped from the distillery to the feed lots, where it is fed in troughs. In addition to the slop an average of about 3 lbs. of cottonseed meal is fed per head daily, with 10 to 15 lbs. of hay, straw, bluegrass chaff, or cottonseed hulls. The roughage and the cottonseed meal are usually mixed with the slop, tho sometimes the steers are permitted to drink the clear slop.

759. Dried brewers' grains.—According to Pott,[72] in Germany dried brewers' grains are well esteemed as a concentrate for fattening mature cattle, meat of good quality being produced on dried brewers' grains, fed as the only concentrate with potatoes, beets, and dry roughage. (**228**)

760. Peanut meal and feed; velvet beans.—*Peanut meal* from hulled nuts is an excellent supplement for cattle, being even higher in protein than is cottonseed meal. In a trial by Burns at the Texas Station[73] peanut meal containing 51.7 per ct. crude protein was compared with choice cottonseed meal containing 44.8 per ct. crude protein, as a supplement to a ration of ground milo, corn or sorghum silage, Bermuda hay, and cottonseed hulls. Due to its higher protein content, less peanut meal was needed to balance the ration than of cottonseed meal. The steers fed peanut meal made slightly more rapid gains than those fed cottonseed meal and returned slightly more profit with both supplements

[69]Nebr. Buls. 100, 132.
[70]Mo. Bul. 90.
[71]Information to the authors.
[72]Handb. Ernähr. u. Futter., II, 1909, p. 241.
[73]Tex. Bul. 263.

at the same price per ton. In this trial the peanut meal did not seem to be quite so palatable as the cottonseed meal. (**258**)

Peanut feed, or ground whole pressed peanuts, containing 36.1 per ct. protein and 22.4 per ct. fiber was found by Burns to be slightly less valuable than cold-pressed cottonseed cake containing 26.8 per ct. protein and 21.2 per ct. fiber.

Velvet beans, commonly fed in the pod, have become an important feed for beef cattle in the South. (**264**) Often corn and velvet beans are grown together and steers are grazed on the crop after most of the ears of corn have been gathered. (**361**)

Velvet beans in the pod should be ground, or soaked for 24 hours to soften the hard pods. In 3 trials by Templeton, Ferguson, and Gibbens of the Alabama Station[74] steers fed velvet beans in the pod and corn or sorghum silage gained on the average 1.55 lbs. a head daily, while others fed cottonseed meal and silage averaged 1.65 lbs. In these trials, with cottonseed meal at $40.00 and silage at $4.00 per ton, velvet beans in the pod were worth $21.80. In a trial by Scott at the Florida Station[75] steers fed a ration of 12 lbs. velvet beans in the pod, 8 lbs. corn, and 10 lbs. cottonseed meal made considerably larger and cheaper gains than others fed 6.5 lbs. cottonseed meal and 25 lbs. cottonseed hulls.

III. Legume Hay and Other Dry Roughages

761. Value of legume hay.—The great importance of hay from the legumes in balancing the carbonaceous grains, such as corn, barley, and wheat, has already been pointed out. (**732**) On account of their richness in protein and also because of their palatability, the legume hays are the most valuable of dry roughages. Even when a ration of corn and such dry carbonaceous roughages as timothy hay, prairie hay, or corn fodder is properly supplemented by linseed or cottonseed meal or some other protein-rich concentrate, smaller gains will nearly always be produced than when the ration consists of corn and legume hay. This is shown in the following table, which summarizes the results secured in 4 trials in which 2-year-old 942-lb. steers were fed for periods averaging 158 days:

Legume hay vs. carbonaceous roughage plus nitrogenous supplement

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain	
		Concentrates Lbs.	Roughage Lbs.
*Lot I, total of 40 steers**			
Legume hay, 9.3 lbs. Corn, 17.9 lbs	2.3	778	405
*Lot II, total of 42 steers**			
Carbonaceous roughage 8.0 lbs. Corn, 16.4 lbs. Supplement, 2.2 lbs	2.0	916	387

*Av. of 1 trial by Bliss and Lee (Nebr. Bul. 151), 1 by Mumford (Ill. Bul. 83), 1 by Skinner and Cochel (Ind. Bul. 115), and 1 by Smith (Nebr. Bul. 90).

[74]Ala. Buls. 192, 198; Cir. 40.

[75]Fla. Bul. 102.

Lot I, fed legume hay and corn, gained on the average 0.3 lb. more per head daily and required 15.1 per ct. less concentrates and about the same amount of roughage as Lot II, fed the equally well-balanced but less palatable ration in which the roughage was prairie hay, timothy hay, or corn stover with a small amount of oat straw. Only when silage, appetizing as well as nutritious, is fed, is it possible to provide a ration which will be equal to one where the roughage is legume hay. (775) Not only will steers fed legume hay make more rapid gains and reach a better finish than those fed such a ration as Lot II received, but also the hogs following the steers will make better gains.

Whether it will pay to chop or grind legume hay or other hay for cattle has been already discussed in the previous chapter. (730)

762. Legume hay plus carbonaceous roughage.—Even on farms where large areas of legumes are raised for hay much carbonaceous roughage, such as corn and sorghum stover, straw, and hay from the grasses, is normally produced in addition. In economical beef production these roughages should be wisely and fully utilized, for while they do not equal legume hay in nutrients or palatability, when judiciously combined with it satisfactory and cheap gains may be secured. This is shown in a 116-day trial by Snyder at the North Platte, Nebraska, Substation[76] in which 425-lb. calves fed sorghum hay during the winter with 2 lbs. a head daily of a mixture of 2 parts corn and 1 part oats gained only 0.4 lb. daily, while another lot fed alfalfa hay instead gained 1.2 lbs. However, a third lot fed alfalfa hay and half sorghum hay made just as large gains as the lot fed all alfalfa hay. Similarly, the gains on prairie hay combined with alfalfa hay were practically as large as when alfalfa was the only roughage.

The good results from combining legume hay with carbonaceous roughage are further shown in a trial by Waters at the Missouri Station.[77] Two-year-old steers fed timothy hay and corn made much smaller gains than those fed clover hay and corn. However, on clover hay, corn stover, and corn, as large gains were produced as when clover hay was the sole roughage.

Smith[78] reports that cattle full fed on corn with alfalfa as the only roughage are more subject to scours, which causes them to go off feed, than when some such carbonaceous roughage as prairie hay, sorghum hay, or corn stover is fed with the alfalfa.

763. Legume hay with cottonseed meal.—Since legume hay is rich in protein it should not be fed as the chief roughage with cottonseed meal, which is itself so rich in this nutrient. In trials at the Texas Station[79] where peanut or alfalfa hay was fed to steers with 5 lbs. of cottonseed meal per head daily, very poor results were secured. When shelled corn was substituted for a part of the cottonseed meal or when prairie hay was fed in place of the legume hay, the gains became normal.

[76]Nebr. Bul. 105.
[77]Mo. Bul. 76.
[78]Nebr. Bul. 116.
[79]Tex. Bul. 76.

Legume hay serves its highest purpose when combined with such carbonaceous concentrates as corn, kafir, and milo. Where cottonseed meal is the chief concentrate, leguminous roughages should be fed in limited amount, at most, along with such carbohydrate-rich roughages as forage from corn or the sorghums, or cottonseed hulls.

764. Clover hay.—The value of this standard roughage of the eastern corn belt compared with timothy hay, when both are fed with corn, is shown in the following table. This summarizes the results of a 180-day trial by Skinner and Cochel at the Indiana Station[80] and a 105-day trial by Waters at the Missouri Station,[81] both with 2-year-old steers:

Clover hay and shelled corn compared with timothy hay and shelled corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.
Lot I, Clover hay, 9.8 lbs.	Shelled corn, 21.5 lbs.....	2.4	919	416
Lot II, Timothy hay, 6.4 lbs.	Shelled corn, 18.8 lbs.....	1.8	1,086	380

In both trials the clover-fed lot ate more grain and roughage than Lot II, fed timothy, and made larger and more economical gains, requiring about 15.4 per ct. less corn for a given increase. Skinner and Cochel report that thruout the experiment the clover-fed steers were in better condition, had better appetites, and were more regular feeders. The timothy-fed steers were irregular in their appetites, and even when eating a full feed seemed unsatisfied. At the close of the 6-months feeding period the average weight of the clover-fed steers was 1,373 lbs., and that of the timothy-fed steers 1,281 lbs. Waters found that corn was worth about 8 cents per bushel more when fed with clover or cowpea hay to fattening steers than when fed with timothy hay. (**312, 347**)

765. Clover vs. alfalfa hay.—On account of the popularity of alfalfa hay as a feed, the relative value of this excellent forage compared with that of red clover hay is a question of much interest. This matter has been studied by Skinner and King in 4 trials at the Indiana Station[82] in each of which they compared the value of clover and alfalfa hay when fed with shelled corn and 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight. Also in 4 trials they compared clover and alfalfa hay when fed with corn silage, shelled corn, and 2.5 lbs. cottonseed meal daily per 1,000 lbs. live weight. When thus fed, clover hay was fully equal to alfalfa hay, ton for ton, any difference in the feeding value of the two kinds of hay being due rather to difference in the quality of the hay than the variety. It should be pointed out that in these trials enough cottonseed meal was fed both lots to balance the rations, even tho no legume hay whatsoever had been fed. Therefore no advantage was secured from the fact that alfalfa hay is much richer than clover in protein. Similar results were secured in a trial by Evvard, Culbertson, and colleagues at the Iowa Station.[83] (**733, 777**)

[80]Ind. Bul. 129.
[81]Mo. Bul. 76.
[82]Ind. Buls. 178, 183, 191, 206, 245.
[83]Information to the authors.

When fed in rations low in protein, alfalfa is worth more per ton than clover hay of equal quality. For example, in a trial by Wilson at the South Dakota Station[84] yearling steers fed only alfalfa hay and corn silage during the first 91 days of the fattening period gained 2.5 lbs. per head daily, while others fed clover hay and silage gained only 2.3 lbs. and required more feed per 100 lbs. of gain. Furthermore, in such rations as shelled corn, corn silage, legume hay, and sufficient cottonseed meal to balance the ration, less of the expensive supplement will be needed if alfalfa hay is fed than if clover hay is used. (777)

766. Alfalfa hay as a nitrogenous supplement.—It has been pointed out previously that when alfalfa hay is fed as the only roughage with corn, which is low in protein, there is no advantage in adding a protein-rich concentrate, for the alfalfa hay is rich enough in protein to balance the ration. (733) When steers are fed silage, however, this succulent feed is so palatable that they will not eat enough alfalfa hay to balance the ration completely. To secure maximum gains it is then necessary to add a protein-rich concentrate, like linseed or cottonseed meal, to provide ample protein. When this is not done, better gains will usually be made on silage, corn, and linseed or cottonseed meal, without any legume hay, than on alfalfa hay, corn, and silage, without the protein-rich supplement. For example, in 3 trials by Tomhave, Severson, and Gerlaugh at the Pennsylvania Station[85] steers fed alfalfa hay and corn silage the first 56 days and then fed shelled corn in addition for 84 days during the finishing period gained only 1.79 lbs. per head daily. Another lot fed only corn silage and 2 to 3 lbs. of cottonseed meal per head daily during the first 56 days, and then shelled corn in addition during the finishing period, gained 2.03 lbs., in spite of the fact that this ration could have been improved by the addition of a little dry roughage, as is shown later. (778) With cottonseed meal at $32.66 and alfalfa hay at $15.00 a ton, the feed cost of the gains was cheaper where alfalfa hay was used as the supplement, but the steers sold for a lower price, due to lack of finish. Hence the net return was $2.30 more per head for the steers fed cottonseed meal.

When steers are to be fed corn with hay from the grasses or such feeds as corn or sorghum stover as the roughage, larger and also cheaper gains will be made if alfalfa hay is used as part of the roughage than if the ration is balanced by the addition of linseed or cottonseed meal. This result, which is shown in trials by Smith at the Nebraska Station,[86] is probably due to the fact that the ration containing alfalfa hay is much more palatable to cattle than when such feeds as timothy or prairie hay are used as the only roughages.

767. Stage to cut alfalfa for beef cattle.—To determine the value of alfalfa hay cut at different stages of growth, McCampbell and Winchester carried on trials during 3 winters at the Kansas Station.[87] The first

[84]Wilson, S. D. Bul. 160.
[85]Penn. Bul. 145.
[86]Nebr. Buls. 100, 116, 132.
[87]Information to the authors.

winter 4 lots, each of 5 calves averaging 440 lbs. in weight, were wintered on alfalfa hay cut at the bud stage, at the early bloom stage, at the full bloom stage, and at the seed stage, respectively. The following winters the same lots of steers were each wintered on hay cut at the same stage as they received the first winter. On the average the steers fed the hay from alfalfa cut at the seed stage gained only 0.47 lb. a head daily and required 3,911 lbs. of hay for 100 lbs. gain. The hay cut at the bud stage produced the largest gains, 1.18 lbs. a head daily, and only 1,628 lbs. hay were required per 100 lbs. gain. However, the alfalfa cut when one-tenth in bloom made hay not much inferior, ton for ton, to this early cutting and yielded 3.71 tons of hay per acre over an 8-year period, while alfalfa cut at the bud stage yielded only 3.26 tons per acre. Considering not only the feeding value of the hay per ton, but also the yield, cutting the alfalfa from one-tenth in bloom to full bloom seemed most profitable.

768. Fattening cattle on alfalfa and other roughage.—In some sections of the West where alfalfa is abundant and the market does not pay a higher price for a well finished animal than for one in only fair flesh, cattle are fed on alfalfa alone or alfalfa and other roughages without concentrates, when they are not marketed directly from the range. In other cases they are fed such roughage alone during most of the feeding period, then a limited amount of concentrates is added for the last month or so to produce somewhat better finish. The results of 8 trials[88] in which western steers have been fed alfalfa hay alone for periods averaging 101 days show that on the average the cattle required 31.3 lbs. hay per head daily, including the hay refused, and that they gained 1.23 lbs. a day. For each 100 lbs. gain there were required an average of 2,541 lbs. hay.

Adding grain or other concentrates to the ration increases the rate of gain and results in better finish, but often makes the gain much more expensive, owing to the low price of hay and the high price of concentrates in these districts. In 6 of the trials mentioned previously, steers were fed alfalfa hay with limited amounts of barley, corn or other concentrates in comparison with the lots fed alfalfa hay alone. On the average each pound of concentrates saved 3.0 lbs. of alfalfa hay, the results differing quite widely in the various trials.

Adding corn silage or sorghum silage to alfalfa hay seems to increase the rate of gain more than adding a limited amount of concentrates, and, furthermore, the gains are usually made at a less cost under conditions in these sections. In a trial by Williams at the Arizona Station[89] steers fed 9.0 lbs. alfalfa hay and 47.1 lbs. sorghum silage gained 2.4 lbs. a head daily, while others fed alfalfa hay alone gained only 1.4 lbs. Similarly, in trials by Potter and Withycombe of the Oregon Station[90] adding corn

[88]Potter and Withycombe, 4 trials, Ore. Bul. 174; Carroll, Utah Station, 2 trials, information to the authors; Foster and Simpson, 1 trial, New Mexico, Bul. 101; Williams, 1 trial, Ariz. Bul. 91.

[89]Ariz. Bul. 91.

[90]Oregon Bul. 174.

silage to alfalfa hay doubled the rate of gain. In the former trial each 100 lbs. of sorghum silage saved 85 lbs. of alfalfa hay, while in the Oregon trials the corn silage was worth even more per 100 lbs. than alfalfa hay, even tho the silage was rather immature. Commonly silage can be produced from corn or other suitable crops at a much lower cost per ton than alfalfa hay, even in the alfalfa districts of the West.

769. Hay from other legumes.—The statements which have been made concerning the high value for beef cattle of alfalfa and clover hay also apply in general to hay from sweet clover, cowpeas, soybeans, field peas, lespedeza, etc. Cowpea or soybean hay is even richer in protein than is alfalfa, and sweet clover and lespedeza contain nearly as much of this nutrient. In a trial by Cochel at the Kansas Station choice first year sweet clover hay was found fully equal to alfalfa hay. Sweet clover hay was also practically equal to alfalfa hay in a trial by Wilson at the South Dakota Station,[91] tho some difficulty was experienced in getting the steers to eat it until it was run thru a hay cutter. (**352**)

Cowpea hay was found fully equal to clover hay in a trial by Waters at the Missouri Station.[92] (**357**)

The value of cowpea hay and other legume hays as a source of protein to balance rations low in this nutrient is well shown in 3 trials by Foster and Smith of the New Mexico Station.[93] Steers fed on the average 8.0 lbs. cowpea hay, 8.2 lbs. ground milo heads and 19.7 lbs. kafir silage gained 2.4 lbs. per head daily, while others fed 2.0 lbs. of cottonseed cake or meal to balance a ration of ground milo heads, kafir silage and dry sorghum fodder or stover gained only 1.8 lbs. On the latter ration the feed cost of 100 lbs. gain was one-third more than when cowpea hay was fed. (**357**)

770. Grazing legumes planted with corn.—In the southern states cowpeas, soybeans, or velvet beans are often grown in the corn field and then fattening cattle are turned in to graze on the crop after most of the corn ears have been gathered. This method not only produces exceedingly cheap gains, but also aids in soil improvement. For example, in a trial at the Arkansas Station[94] 5 steers grazed on a 5-acre field of corn and cowpeas, after the corn ears had been harvested, gained 2 lbs. a head daily for 64 days. The steers were fed in addition a small amount of cotton seed, but only consumed 194 lbs. for each 100 lbs. gain.

771. Fodder and stover from corn and the sorghums.—When fed as the only roughage, fodder or stover from corn or the sorghums is much inferior to corn silage or to legume hay, even tho protein-rich supplements are added to balance the ration.

In a trial by Bohstedt at the Ohio Station[95] corn stover gave poor results compared with corn silage, when fed with shelled corn, mixed hay, and enough linseed meal to balance the ration. With corn stover at $7 a ton and corn silage at $4, the steers fed silage returned $6.14 each

[91]S. D. Bul. 160.
[92]Mo. Bul. 76.
[93]New Mex. Bul. 108.
[94]Ark. Bul. 58.
[95]Information to the authors.

over the cost of feed, while the net return for those fed stover was only 81 cents.

However, bright, well-cured fodder or stover is satisfactory as part of the roughage, when fed either with silage or with legume hay. Stover can not form a large part of the ration for fattening cattle, as it is low in digestible nutrients. For carrying stocker cattle or breeding cows thru the winter, it may be fed in larger amounts. As is pointed out later, corn stover silage is more valuable than dry corn stover. (**781**)

Corn fodder of good quality, fed with legume hay, may make practically as large gains on fattening cattle as tho they were fed silage. It is shown elsewhere that the chief advantage of silage over dry corn fodder lies in the smaller amount of feed required for 100 lbs. gain by silage-fed cattle. (**298, 780**)

The value of *corn stover* is well shown in trials by Smith at the Nebraska Station[96] in which steers were fed corn with alfalfa hay as the only roughage, while in other lots half the alfalfa hay was replaced by corn stover. The steers fed the corn stover made as large gains as those fed only alfalfa hay as roughage, and the gains were materially cheaper.

Sorghum fodder and stover, both from the grain sorghums and also from the sorgos, are useful feeds in beef production when fed with legume hay or with sufficient amounts of protein-rich supplement to balance the ration. Just as with corn forage, sorghum silage is more efficient and more economical than dry sorghum fodder, and sorghum stover silage is preferable to dry sorghum stover. For example, in a trial at the Fort Hays, Kansas, Branch Station[97] McCampbell found that for beef breeding cows one acre of kafir stover silage (made into silage after the heads had been removed) had a feeding value equal to 2.2 acres of dry kafir stover. Similarly, an acre of kafir silage (with the heads on) equalled 2.58 acres of dry kafir fodder with heads on.

772. Hay from the grasses; straw.—It has been previously pointed out that when cattle are fed as the only roughage *hay from the grasses,* such as timothy or prairie hay, smaller and less economical gains will be produced than if they are fed legume hay. This is true, tho to a less extent, even when a protein-rich supplement is added to balance the ration. (**761, 764**) On the other hand, when cattle are full fed on all the silage they want, hay from the grasses can well be used to satisfy their desire for dry roughage, provided sufficient supplement is fed to balance the ration. Also, even when silage is not available, such hay gives fairly good results when fed as only half the roughage, along with good legume hay. (**766**)

Timothy hay was worth much less per ton than clover or alfalfa hay in a trial by Evvard, Culbertson, and colleagues at the Iowa Station[98] when fed as the only roughage, with shelled corn and cottonseed meal.

[96]Nebr. Buls. 90, 93, 100.

[97]Kans. (Hays) Branch Sta., Rpt. of Progress of Beef Cattle Expts., 1919-20.

[98]Information to the authors.

Mixed clover and timothy hay, containing one-third to one-half clover, was midway between pure timothy and pure clover hay in value.

Sheaf oats, a common feed in Western Canada, was worth about one-fifth more per ton than prairie hay for fattening steers in a trial by Dowell and Bowstead at the University of Alberta.[99]

Straw is too low in nutrients to form any large part of the ration for fattening cattle, but may be economically fed in greater amounts to breeding cows or stock cattle. However, as is pointed out later, when steers are fed corn grain, corn silage, and enough cottonseed or linseed meal to balance the ration, bright oat straw will satisfy their desire for dry roughage and produce as rapid gains as if legume hay were fed. (778) Barley straw is nearly equal to oat straw, while wheat straw is not so valuable and rye straw is of little worth as a feed.

773. Cottonseed hulls.—For many years cottonseed hulls and cottonseed meal formed the standard ration for fattening cattle in the South. On this combination steers make surprisingly good gains when the amount of cottonseed meal is not excessive nor the period too long extended. Otherwise trouble from cottonseed meal poisoning may be encountered. The relative value of cottonseed hulls and corn silage for fattening cattle is shown in the following table, in which are averaged the results of 9 trials at 5 different stations with steers fed for periods averaging 107 days.

Cottonseed hulls vs. corn silage for fattening steers

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Cottonseed meal Lbs.	Feed for 100 lbs. gain Hulls or silage Lbs.	Feed cost of 100 lbs. gain Dollars
*Lot I, total of 141 steers**					
Cottonseed hulls, 25.6 lbs. Cottonseed meal, 6.8 lbs	914	1.6	442	1,629	12.35
*Lot II, total of 131 steers**					
Corn silage, 42.1 lbs. Cottonseed meal, 6.8 lbs.....	918	1.8	418	2,478	10.22

*Average of 4 trials by Curtis (N. C. Buls. 199, 218, 222); 1 by Lloyd (Miss. Station, information to the authors); 1 by Smith (S. C. Bul. 160); 1 by Ward and Gray (U. S; Da. Bul. 762); and 2 by Willson (Tenn. Bul. 104).

In these trials the steers fed silage usually made slightly larger gains than those receiving hulls, but the chief difference was that with a single exception the silage-fed lot made by far the cheaper gains. The silage-fed steers almost uniformly showed better finish and better handling quality than those fed hulls. It has already been shown that the longer the feeding period, the greater is the superiority of silage over hulls, for silage feeding delays any injurious effects of the cottonseed meal. In these trials 100 lbs. of silage was worth as much as 68 lbs. of cottonseed hulls, considering merely the feed required for 100 lbs. gain and disregarding the better finish of the silage-fed cattle. This shows clearly that at prevailing prices it is usually cheaper in the South to raise silage for roughage than to feed cottonseed hulls exclusively.

[99]Information to the authors.

It is pointed out later that steers commonly make more rapid gains when fed some dry roughage than when silage is the only roughage used. (778) Consequently it is often desirable to use a combination of hulls and silage, or else feed in addition to the cottonseed meal and silage some cheap farm-grown dry roughage, such as corn or sorghum stover, straw, or perhaps hay.[100] One can readily decide what roughages are the most economical under his own conditions by determining which actually furnish total digestible nutrients the cheapest, in the manner discussed in Chapter VIII. (191-6)

III. Succulent Feeds

774. Importance of silage in beef production.—The use of silage is fast revolutionizing the feeding of beef cattle, just as it has the feeding of milk cows in the leading dairy sections of our country. Wherever either corn or the sorghums thrive, silage from these crops, cut when well matured, has proved of great value in cheapening the cost of beef production. (411) As is shown later (788-90), breeding cows and stock cattle may be maintained in winter in good condition on silage from well-matured corn or the sorghums, with a limited amount of legume hay or a small allowance of such nitrogenous concentrates as cottonseed or linseed meal. For growing animals this palatable succulence can not be excelled, when fed in proper combination with legume hay or concentrates rich in protein. (798-9)

On well-balanced rations in which silage is the chief roughage fattening cattle will fatten rapidly and reach a high finish on a moderate allowance of expensive concentrates. At first it was thot that silage-fed cattle shrank more in shipment than those finished on dry roughage. Trials have now abundantly demonstrated, however, that if silage is withheld for the last day or two before shipment and dry roughage fed instead, cattle thus fattened will not shrink any more than those receiving no silage.

Trials at various stations have shown that it is commonly more economical to give fattening cattle twice a day all the silage they will clean up without undue waste, rather than to limit the amount of silage fed. Two-year-old steers full-fed on corn, legume hay, and silage will eat 30 to 40 lbs. of silage a day during the first month of fattening and gradually less as feeding progresses, until during the last month they will eat only 10 to 20 lbs. a day. Commonly they will show such a preference for silage compared with even choice legume hay, that they will eat on the average only 3 to 6 lbs. of hay per day during the fattening period.

The question as to how much corn or other grain it is profitable to feed to steers given an unlimited allowance of silage is fully discussed elsewhere. (715-6)

[100] U. S. D. A. Buls. 628, 762; Tex. Buls. 198, 263.

775. Corn silage.—Silage from well-matured corn, carrying an abundance of ears and consequently a high proportion of corn grain, is the best of all silage for beef cattle. (**296-9**) Such silage aids materially in reducing the amount of concentrates which need be supplied in addition. To show the good results from feeding corn silage there are summarized in the following table the results of 20 trials where a full feed of corn silage was added twice a day to the already excellent ration of shelled corn, cottonseed or linseed meal, and clover or alfalfa hay. In these trials a total of 377 two-year-old steers averaging 978 lbs. in weight were fed for an average of 153 days.

Value of corn silage when added to an already excellent ration

Average ration	Daily gain	Feed for 100 lbs. gain			Feed cost of 100 lbs. gain
		Concentrates	Hay	Silage	
	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
*Lot I, no silage**					
Legume hay, 11.3 lbs.					
Shelled corn, 16.8 lbs.					
Supplement, 2.7 lbs	2.41	810	474	.....	13.47
*Lot II, fed silage**					
Corn silage, 26.4 lbs.					
Legume hay, 3.4 lbs.					
Shelled corn, 13.9 lbs.					
Supplement 2.7 lbs	2.43	685	141	1,101	12.25

*Average of 14 trials by Skinner, Cochel, and King (Ind. Buls. 129, 136, 153, 167, 178, 191, and 206); 2 by Evvard and Pew, Iowa Station (Breeder's Gaz., 61, 1912, p. 1,040, and Iowa Bul. 182); 2 by Gramlich, Nebr. Station (Information to the authors); 1 by Allison (Mo. Bul. 112); and 1 by Peters and Carnes, Minn. Station (Information to the authors).

The steers in Lot II, fed silage, consumed 26.4 lbs. per head daily and ate 2.9 lbs. less corn and 7.9 lbs. less legume hay than those in Lot I. The silage ration did not produce appreciably larger gains than did legume hay fed as the only roughage. The chief advantage from feeding silage was the cheapness of the gains when this economical feed was used. Silage feeding reduced the feed cost of each 100 lbs. gain $1.22, a sum which would often make the difference between a loss and a profit on the feeding operations.

In these trials each ton of corn silage saved on the average 227 lbs. of concentrates (practically all corn) plus 605 lbs. clover hay. With concentrates at only $20.00 per ton and clover hay at $14.00 per ton, corn silage was worth $6.50 a ton. This is considerably more than the cost of production on most farms, showing plainly the economy of silage for beef production under corn-belt conditions. In 2 trials with calves being fattened for baby beef by Cochel at the Kansas Station,[101] silage had a similar high value, showing it is just as satisfactory for younger steers as for 2-year-olds.

For silage in the northern states a variety of corn should be grown which will nearly mature in the average season, rather than attempting to grow a rank-growing, late-maturing kind. Immature, watery silage is of much lower feeding value than that from corn cut when the kernels

[101]Information to the authors.

have hardened and glazed, but while most of the leaves are still green. This has been clearly shown in trials with fattening steers by Wilson, Kuhlman, and Thompson at the South Dakota Station.[102] At the proper stage of maturity the kernels of dent varieties will be well dented.

It is usually wise to plant corn for silage somewhat more thickly than that for grain alone. However, there should be enough space for the plants to develop good ears, since grain is needed to furnish the net energy required to make rapid gains.

In the South Dakota trials and also in a trial by Winchester at the Kansas Station[103] silage from corn which was allowed to stand in the field until it was practically mature and the leaves had largely turned brown was decidedly inferior to silage from corn cut at the dent stage. However, it was a fairly satisfactory feed, and produced better results than would have been secured from dry fodder. If for any reason corn can not be ensiled until it is past the proper stage, care should be taken to add water to ensure the silage keeping. (**299-300**)

In districts where choice alfalfa hay is very cheap, compared with other feeds, and corn or other grain is also low in price, the most economical ration may be merely these feeds, without any silage. For example, in 4 trials by Gramlich at the Nebraska Station[104] steers full-fed on shelled corn and alfalfa hay gained 2.42 lbs. a head daily and required 699 lbs. corn and 438 lbs. hay for each 100 lbs. gain. Others full-fed corn silage in addition gained only 2.12 lbs. a day and required for 100 lbs. gain 511 lbs. corn, 192 lbs. hay, and 1,520 lbs. silage. In these trials the silage-fed steers did not reach quite as good a finish as those fed only corn and hay. When linseed meal was added to the ration of silage, hay, and corn to balance it better, the gains were increased slightly, but did not come up to those produced by the home-grown alfalfa hay and corn ration. Considering all factors, corn silage was not worth one-third as much per ton as choice alfalfa hay under these conditions.

776. Feeding a supplement with full feed of silage.—We have seen earlier in this chapter that when fattening cattle are fed corn with clover or alfalfa hay as the only roughage, they eat sufficient of the protein-rich hay to balance their ration fairly well. (**733**) Hence adding a supplement, such as cottonseed or linseed meal, does not greatly increase the gains. However, if the cattle are fed all the corn silage they will eat in addition to corn and legume hay, the silage is so palatable that they will then generally eat but 3 to 6 lbs. of hay per head daily. The following table, summarizing the results of 7 different trials, shows that this small amount of clover hay is not sufficient to balance the ration properly for 2-year-old steers.

[102]S. D. Buls. 182, 189.

[103]Kan. Cir. 92.

[104]Information to the authors.

Adding a supplement to corn, corn silage, and clover hay

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain: Concentrates Lbs.	Hay Lbs.	Silage Lbs.
*Lot I, no supplement**					
Shelled corn, 14.4 lbs. Corn silage, 26.1 lbs. Clover hay, 3.8 lbs	984	2.1	710	189	1,271
*Lot II, fed a supplement**					
Supplement, 2.7 lbs. Shelled corn, 14.2 lbs. Corn silage, 26.1 lbs. Clover hay, 3.8 lbs	984	2.6	664	150	1,059

*Average of 6 trials by Skinner, Cochel, and King (Ind. Buls. 129, 220, 240, 249, and 255), and of 1 trial by Allison (Mo. Bul. 112).

The steers in Lot II, fed 2.7 lbs. of protein-rich supplement (cottonseed or linseed meal) in addition to shelled corn, corn silage, and clover hay, gained 0.5 lb. more per head daily than Lot I, receiving no supplement, and required less feed for 100 lbs. gain. Because the price of these supplements per ton is much higher than that of corn, the steers fed the supplement made no cheaper gains in these trials than those receiving none. However, they sold for 26 cents more per cwt. on account of better finish. Taking into consideration both the saving of feed per 100 lbs. gain when the supplement was fed and also the higher selling price, 1 lb. of cottonseed or linseed meal was worth as much as 3 lbs. of shelled corn.

In these trials just as good results would probably have been secured if only 2.25 to 2.50 lbs. of cottonseed or linseed meal had been fed per head daily, which would have made the gains slightly more economical than on the larger allowance. (**710**)

Since alfalfa hay is materially richer in protein than is clover hay, a ration of corn, alfalfa hay, and corn silage is more nearly balanced than when clover hay is fed. Therefore, there is less advantage in adding an allowance of cottonseed or linseed meal. This matter has been studied in 4 trials with 2-year-old steers by Gramlich at the Nebraska Station[105] and in 2 by Allison at the Missouri Station.[106] On the average the steers fed shelled corn, alfalfa hay, and corn silage, without a supplement, gained 2.22 lbs. a head daily, while the gain was increased to 2.47 lbs. when an allowance of cottonseed or linseed meal was added. This shows that the ration of corn, alfalfa hay, and corn silage, the nutritive ratio of which averaged 1 : 9.0, did not contain quite enough protein for the maximum gains of 2-year-old steers. However, the steers fed no supplement were, on the average, nearly as well finished as the others at the end of the feeding period, selling for only 6 cents less per cwt. Considering all factors, when cottonseed or linseed meal was added to the ration of corn, alfalfa hay, and corn silage, 100 lbs. of the supplement was worth only about as much as 160 lbs. of shelled corn. Therefore,

[105]Information to the authors. [106]Mo. Bul. 150.

when these supplements are higher in price than this, compared with corn, it will usually be most profitable not to add the supplement to this ration. In 4 of these trials the profit was greater and in 2 it was less when the supplement was fed, with feeds at the current prices.

777. Amount of supplement to feed with silage.—There have been but few trials carried on thus far to find definitely how much protein-rich supplement should be added to corn grain, corn silage, and legume hay for fattening steers. On studying this important point Skinner and King found in 2 trials at the Indiana Station[107] that 2-year-old steers fed 2.5 lbs. cottonseed meal daily per 1,000 lbs. live weight in addition to shelled corn, clover hay, and corn silage gained a little more rapidly than those fed only 1.25 lbs. cottonseed meal daily per 1,000 lbs. live weight. This indicates that the latter ration, which had a nutritive ratio of about 1:7.9, was slightly too wide for the maximum gains of 2-year-old steers. In other trials they found that there was no advantage in feeding more than 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight to 2-year-old steers full-fed on corn, clover hay, and corn silage. In fact, the gains were smaller and less economical when the allowance of cottonseed meal was increased to 4.0 lbs. The nutritive ratio of this ration was 1:5.6, which about met the recommendations of the old Wolff-Lehmann feeding standards. Similarly Allison found at the Missouri Station[108] that steers fed corn silage and clover hay, without any additional corn grain, gained just as fast when fed 2.8 lbs. linseed meal a head daily as when the allowance was increased to 4.4 lbs.

When alfalfa, cowpea, or soybean hay is fed with corn grain and corn silage, obviously less protein-rich supplement will be needed to balance the ration and produce maximum gains than when clover hay is used, for these hays are higher than clover in protein. On the other hand, when no legume hay is fed, the allowance of supplement should be increased. A safe guide to follow is to feed enough supplement to give a nutritive ratio of 1:7 to 1:8, as is advised in the Morrison feeding standards, unless such supplements as linseed or cottonseed meal are unusually high in price compared with the other available feeds. (710) If cottonseed or linseed meal costs more than 2.5 to 3 times as much per ton as does corn or other grain, then cheaper gains and greater profit will often be made if no supplement is added, provided legume hay is fed in addition to silage. However, if no leguminous forage is supplied, then a protein-rich supplement is always necessary for the best results.

778. Silage as the only roughage.—Whether steers fed silage alone for roughage will make as large gains as those supplied some hay or other dry roughage in addition, is a question of great importance to the cattle feeder, as dry roughages are often more expensive than silage. The following table summarizes the results of 9 trials, in each of which corn silage was fed as the sole roughage with corn and a nitrogenous supplement (cottonseed or linseed meal) to one lot of steers, while

[107]Ind. Buls. 153, 167, 178. [108]Information to the authors.

another received the same feeds with legume hay in addition. In these trials a total of 174 two-year-old steers averaging 942 lbs. were fed for an average of 156 days.

Silage as the sole roughage vs. silage and legume hay

Average ration	Daily gain Lbs.	Feed consumed for 100 lbs. gain			Feed cost of 100 lbs. gain Dollars
		Concentrates Lbs.	Hay Lbs.	Silage Lbs.	
*Lot I**					
Corn silage, 29.2 lbs. Corn, 13.5 lbs. Supplement, 2.7 lbs.....	2.24	693	...	1,283	9.13
*Lot II**					
Legume hay, 4.3 lbs. Corn silage, 24.3 lbs. Corn, 13.8 lbs. Supplement, 2.7 lbs.....	2.36	701	195	1,065	9.87

*Av. of 5 trials by Skinner, Cochel, and King (Ind. Buls. 136, 153, 163, 167); 1 by Allison (Mo. Bul. 112); 1 by Evvard at the Iowa Station (Breeder's Gaz., 61, 1912, p. 1040); 1 by Rusk at the Ill. Station (Breeder's Gaz., 61, 1912, p. 1041); and 1 by Tomhave and Hickman (Penn. Bul. 133).

Lot II, receiving legume hay in addition to corn silage, made slightly larger gains than Lot I, which was fed no dry roughage. The addition of clover hay to the ration increased the feed cost of 100 lbs. gain by $0.74 on the average but resulted in slightly better finish, the steers in Lot II selling for 7 cents more per 100 lbs. than those in Lot I. In some of the trials the selling price of Lot II was enough higher to offset the more expensive gains, and return a greater profit. In others, feeding silage as the only roughage was the more economical. Where the silage was from corn which had nearly matured and hence was high in dry matter, the addition of dry roughage did not always increase the gains.

As steers fed clover hay in addition to corn silage ate but little hay, Skinner and King thot that possibly the benefit from the hay lay more in satisfying the appetites of the steers for dry roughage than in the nutrients actually supplied. They tested this theory out in two trials in which oat straw was fed in place of clover hay, the rest of the ration consisting of shelled corn and corn silage, with enough cottonseed meal to balance the ration. Tho the steers ate an average of but 1.5 lbs. oat straw, this seemed to satisfy their desire for dry roughage, and in both trials they made as large gains, at a less cost for feed, and sold for fully as high a price as those fed clover hay. It should be pointed out that these results would not have been secured had not sufficient cottonseed meal been fed to balance the oat straw, corn silage, and corn ration.

Trials at other stations[109] show likewise that adding some dry roughage to a ration of grain, silage, and protein-rich supplement will usually produce slightly more rapid gains and better finish on the cattle than when silage is the only roughage. An important fact for the farmer who does not have an abundance of home-grown legume hay is that this dry

[109]Bliss and Lee, Nebr. Bul. 151; McCampbell and Winchester, Kan. Cir. 92; Wilson, S. D. Bul. 137.

roughage may consist of such cheap material as oat straw, prairie hay, or fodder and stover from corn or the sorghums, provided a protein-rich concentrate is fed to balance the ration.

This is not a matter of concern to the farmer who wisely has his crop rotations planned so that he normally has plenty of legume hay for his stock. He appreciates the fact that for him legume hay is a cheap feed, no matter what its market price may be. Under proper conditions he knows he can secure heavy yields of nutritious hay at low cost. Furthermore, he realizes that the legume crop not only enriches his fields as it grows, but also again adds a rich store of fertility, when the manure resulting from feeding the crop is returned to the soil.

779. Amount of concentrates to feed with silage.—The question as to how much corn or other grain it is most profitable to give steers full fed on silage has been fully discussed in the previous chapter. (**715-6**) Recent trials have shown clearly that steers will make quite good gains and reach a fair finish when fed only good corn silage, legume hay, and a small allowance of cottonseed meal or linseed meal to balance the ration. When grain is high in price and the market does not pay a considerable premium for well-finished cattle, such a ration will usually make the largest profit. On the other hand, when grain is low in price, it is usually wisest to feed a fairly liberal allowance of it to fattening cattle, even tho they are receiving silage from well-eared corn.

780. Corn silage vs. shock corn.—The superiority of corn silage over shock corn or corn fodder is well shown in a trial by Mumford at the Illinois Station[110] in which growing beef calves were fed either corn silage or shock corn from the same field, with 2 lbs. of oats and 4.0 to 4.6 lbs. of mixed hay per head daily. The silage-fed calves made slightly larger gains, but the chief advantage lay in the fact that more of the shock corn was wasted and hence the corn from a much larger area was needed to feed the steers getting shock corn than for those fed silage. Taking everything into consideration, the corn silage from an acre was worth 30 per ct. more than the shock corn from the same area. In a trial by Allison at the Missouri Station[111] with fattening steers the difference was still greater, silage being worth over 50 per ct. more than the shock corn from the same area.

In a trial by Evvard, Culbertson, and colleagues at the Iowa Station[111a] steers fed corn, cottonseed meal, alfalfa hay, and corn silage gained 2.66 lbs. a head daily while others fed corn, cottonseed meal, and corn fodder, without alfalfa hay, gained only 1.97 lbs. The silage-fed steers returned $10.07 each over the cost of feed while those fed stover failed by $1.41 a head of paying for their feed.

781. Corn stover silage.—It is pointed out in the next chapter that corn stover silage (made from field-cured fodder from which the ears have been removed) is often an economical feed for wintering beef breeding cows or stock cattle. Such animals do not require rations very rich

[110]Ill. Bul. 73. [111]Mo. Bul. 112. [111a]Information to the authors.

in net energy and therefore differ radically in their feed requirements from cattle which are being fattened. These need rations high in digestible nutrients and net energy, to permit rapid gains in weight. (**80, 129-130**) It is evident, therefore, that corn stover silage is not a very good substitute for corn silage for fattening cattle. In a trial by Winchester at the Kansas Station[112] yearling steers fed corn silage containing all the ears, along with 1 lb. of cottonseed meal per head daily to balance the ration, but with no other feeds, gained 1.87 lbs. per head daily. On the other hand, when corn stover silage was substituted for the corn silage, steers gained only 0.33 lb. daily. Gayle likewise found corn-stover silage a very inefficient feed for fattening steers compared with normal corn silage, in a trial at the Mississippi Station.[113] While corn stover silage is much inferior to corn silage for fattening cattle, it is decidedly better than dry corn stover, as it is more palatable and is consumed with less waste.

Similar results were secured in 2 trials by Brown at the Michigan Station.[114] Steers fed normal corn silage, with clover hay, a small amount of cottonseed or linseed meal, and 4.7 lbs. corn gained 2.16 lbs. a head daily. Other steers fed corn stover silage instead of normal silage gained only 1.57 lbs. a head daily, even tho they were fed 0.7 lb. more shelled corn per head daily. A third lot, fed similarly on corn stover silage, except that the allowance of shelled corn was increased to 8.4 lbs. a day, gained only 1.80 lbs. With normal silage at $4.00 a ton and corn stover silage at only $1.60 a ton, the feed cost of 100 lbs. gain, after crediting the gains made by the pigs following the steers, was decidedly lower when normal silage was fed. This shows that the corn stover silage was not even worth 40 per ct. as much a ton as normal corn silage in these trials.

These trials, together with the results which have been secured with dairy cattle (**301, 632**), show that it is a waste not only of labor but also of feed to husk corn before ensiling it for animals being fed for production. On the other hand, corn stover silage may be a very economical feed for maintaining beef breeding cows or for wintering stocker steers, as is pointed out in the next chapter.

Many farmers think that a considerable part of the feeding value of the corn grain is lost when the whole crop is ensiled. They believe that if they husk out the corn and later feed it with silage made from the stover, the feeding value of the crop is greater. Winchester found, however, that the opposite is true. Steers fed corn stover silage plus the corn which had been removed when the crop was ensiled, made smaller and less economical gains than those fed the silage containing the ears. In fact, in this trial the corn grain in the silage was worth 12 per ct. more than the same amount of corn husked out, shelled, and fed in this form to the steers.

[112]Kan. Cir. 92.

[113]Miss. Bul. 182.

[114]Information to the authors.

782. Silage from kafir and other sorghums.—In silage from the sorghums the feeder of the semi-arid districts has an admirable substitute for corn silage. In 3 trials by Cochel at the Kansas Station[115] steer calves were wintered on about 26 lbs. of corn, kafir, or sweet sorghum silage per head daily, with 1 lb. of cottonseed meal or linseed meal in addition. All lots made satisfactory gains and the several kinds of silage had nearly the same feeding value per ton, kafir silage being fully equal to corn silage and sweet sorghum silage being of slightly lower value. However, the acre yield of sweet sorghum silage was 16.9 tons, while corn yielded 12.1 tons and kafir slightly less. Considering this fact, the sweet sorghum silage was the cheapest. In dry seasons in this section, corn may be injured by drought so much that the crop is practically a failure, while a fair yield of silage will be secured from the sorghums.

Under the humid conditions of the corn belt and the southeastern states, sweet sorghum will often produce a larger tonnage of silage than corn. To determine which crop is more profitable to raise in this district for fattening cattle, Good, Horlacher, and Grimes carried on trials with 2-year-old steers during 3 years at the Kentucky Station.[116] Each year one lot of steers was fed sorghum silage, corn grain, and wheat straw, with cottonseed meal to balance the ration, while another lot received corn silage in place of the sorghum silage. One year soybean straw and corn stover were fed to each lot in addition. The steers fed sorghum silage gained less rapidly in each trial, on the average the daily gain per head being 0.24 lb. less than for the steers fed the corn silage. Furthermore, these steers required considerably more feed for 100 lbs. gain and they sold for 12 cents less per cwt., due to a trifle poorer finish. On the other hand it was found that during a five year period an average of 16.78 tons of sorghum silage was secured per acre compared with 10.75 tons for corn silage, or 56 per ct. more from sorghum. The greater yield of sorghum silage did not, however, fully offset the other advantages of corn silage. Considering all factors, it was concluded that growing sorghum for silage was only 92 per ct. as economical as raising corn for silage. In 2 trials by Gayle at the Mississippi Station[117] sorghum silage was also worth considerably less per ton than corn silage. From these trials we may conclude that under humid conditions corn silage is usually more profitable than sorghum silage for beef production.

783. Silage from other crops.—Several other crops furnish satisfactory silage for beef production. In fact in nearly every district of the country some economical crop may be grown.

Sunflower silage has attracted much attention in the last few years, as has already been pointed out. (**384, 636**) Sunflower silage has been compared directly with corn silage in trials by Blizzard at the Oklahoma Station[118] and by Fuller, Morrison, and Sommerfeld at the Wisconsin

[115]Amer. Soc. Anim. Prod., Proceedings, 1915-16, pp. 9-14.

[116]Ky. Bul. 233. [117]Miss. Bul. 182. [118]Okla. Buls. 134, 139.

Station.[119] In both trials the steers fed sunflower silage made as rapid gains as those fed corn silage and required about the same amount of feed for 100 lbs. gain. However, much more pork was produced by the pigs following the steers fed corn silage. Hence, considering this fact, the sunflower silage was worth only about half as much per ton as the corn silage in the Oklahoma trial and in the Wisconsin experiment only 78 per ct. as much per ton. In two trials by Blizzard sunflower silage was about equal to darso silage. In other trials[120] it has had a relatively low value. Until more information is available, it would not seem wise to grow it as a substitute for corn silage in districts where corn thrives. In some sections where the climate is too cool for corn, sunflowers appear to be a very promising substitute.

Proso millet silage was found by Wilson and Kuhlman at the South Dakota Station[121] to be a fair silage crop for beef cattle, tho decidedly inferior to silage from well-matured corn and worth even less than silage from immature corn, ensiled when it was beginning to tassel. (317)

Many farmers now grow *soybeans* or *cowpeas* with corn or sorghum and ensile the entire crop or else raise soybeans separately and mix with the corn as the silo is filled. *Corn and soybean silage,* made by mixing 1 ton of green soybean fodder with 2 tons of green corn fodder as it was ensiled, was compared with corn silage in 4 trials at the Indiana Station[122] by Skinner, King, and colleagues. The protein-rich corn and soybean silage did not have any appreciably higher value, ton for ton, than the corn silage, even when fed with shelled corn and clover hay, which ration, as we have seen, does not contain enough protein for maximum gains. That the corn and soybean silage was not worth more per ton than the corn silage was probably due to the fact that it was lower in net energy, because the soybean forage did not contain as much grain as the corn forage. This would offset the higher protein content of the mixed silage.

Oats or *oats and peas* furnish a satisfactory silage crop for northern sections. In a trial by Dowell and Flack at the University of Alberta, Canada,[123] oat silage was much superior to sunflower silage for fattening steers and even better than oat and pea silage. In trials by Faville at the Wyoming Station[124] oat and pea silage proved excellent for beef cows, growing cattle, and stocker steers.

784. Roots.—Wherever corn or the sorghums thrive, silage from these crops provides cheaper succulence than do roots. In northern districts where root crops flourish but where corn will not mature sufficiently for silage, roots are a valuable feed for beef cattle.

[119]Unpublished data.

[120]Dowell and Flack, University of Alberta, Canada, information to the authors; Wilson and Kuhlman, South Dakota, information to the authors.

[121]S. D. Bul. 189.

[122]Ind. Buls. 220, 240, 249, and 255.

[123]Information to the authors.

[124]Wyo. Bul. 108.

In trials by Day and by Blair in Canada[125] corn silage was worth considerably more per ton than roots for fattening cattle, due to the fact that roots are much more watery than silage. When only a few pounds per head daily of roots are fed to cattle as an appetizer, they may be worth as much, pound for pound, as corn silage.[126]

785. Sweet potatoes, cassava, Japanese cane.—In some sections of the southern states these crops are of importance for beef production. In a trial at the Florida Station[127] steers fed 35 lbs. of either sweet potatoes or of cassava roots with 10 lbs. of cowpea hay and 4 lbs. of cottonseed meal made satisfactory and economical gains. Scott[128] found that some dry roughage should be fed with sweet potatoes, as otherwise they are too laxative. In another trial by Scott[129] 930-lb. steers fed an average of 21.3 lbs. Japanese cane, 7.3 lbs. corn, and 4.2 lbs. cottonseed meal gained 1.6 lbs. per head daily for 90 days, requiring 698 lbs. of concentrates and 1,298 lbs. of Japanese cane for 100 lbs. gain.

786. British system of fattening cattle.—The great value of succulence in reducing the amount of high-priced concentrates needed to fatten cattle is well shown in the extensive compilation by Ingle[130] of all the cattle-feeding trials carried on in Great Britain between the years 1835 and 1908—201 in number. From this report the following examples are chosen as broadly illustrating the British system of fattening beef cattle.

Rations used by British farmers in beef production

Average ration	No. fed	Initial weight Lbs.	Daily gain Lbs.	Total gain per head Lbs.
Shorthorns, 2 to 5 years old, fed 98 days				
Swedes, 171 lbs. Linseed cake, 2.4 lbs.				
Straw, 14 lbs. Corn meal, 2.0 lbs	4	1,305.0	3.0	292
Irish yearlings, fed 112 days				
Turnips, 50 lbs. Cottonseed cake, 3.6 lbs.				
Oat straw, 8.4 lbs. Dried brewers' grains, 5.8 lbs	10	942.2	1.3	149
Irish 2-year-olds, fed 133 days				
Roots, 112.0 lbs.				
Hay and straw, 8.0 lbs. Linseed cake, 8.7 lbs	4	1,030.4	2.1	280
Aberdeen-Angus, fed 112 days				
Mangels, 108.8 lbs.				
Oat straw, 8.0 lbs. Cottonseed cake, 3.0 lbs	6	947.6	1.9	211
Galloways, 2 to 3 years old, fed 100 days				
Swedes, 150.0 lbs.				
Oat straw, 7.0 lbs. No concentrates	3	933.0	1.4	143
Irish 3-year-olds, fed 88 days				
Pasture Cottonseed cake, 2.8 lbs.				
Corn meal, 2.8 lbs	10	876.2	3.7	322
Shorthorn 3-year-olds, fed 123 days				
Swedes, 40.5 lbs. Cottonseed cake, 5.0 lbs.				
Hay, 16.2 lbs. Linseed cake, 3.0 lbs.				
Barley, 1.0 lb	8	1,178.4	2.4	294

[125]Day, Ont. Agr. Col., Rpts. 1901, 1902; Blair, Rpt. Dominion Expt. Farms, 1917, p. 72.

[126]Wilson, S. D. Bul. 137.

[127]Fla. Rpt. 1901.

[128]Fla. Rpt. 1909.

[129]Fla. Rpt. 1912.

[130]Trans. Highl. and Agr. Soc. of Scotland, 1909.

The American cattle feeder who critically reviews the data given will be impressed first of all with the suprisingly small amount of concentrates employed in the ration. In the 201 trials presented by Ingle the largest amount of concentrates fed per head daily to any lot was 13 lbs. In a few cases no concentrates were fed, but usually the allowance for each bullock was 6 or 7 lbs. per day. The rich nitrogenous concentrates, such as linseed meal, cottonseed meal, dried brewers' and distillers' grains, and peanut cake are the ones commonly employed, followed by barley and corn meal more sparingly used. Equally striking is the heavy use of roots, the amount fed ranging from 35 lbs. per head daily to above 150 lbs. in extreme cases. The light feeding of concentrates and the heavy feeding of roots is accompanied by the large consumption of hay and straw, which the British feeder chaffs or cuts, and mixes with the pulped or sliced roots and meal before feeding. It will be further observed that the British farmer generally feeds quite mature bullocks, and that the feeding period is relatively short, ranging from 80 to 120 days. It is probable that the cattle are usually in good flesh when the feeding begins.

In studying these figures we should remember that it was the British farmer who originated and developed all the valuable breeds of beef cattle now scattered over the globe, and his ability and success in producing beef of high quality is unquestioned. It has been pointed out in the previous chapter that when concentrates are high in price, our feeders may wisely adopt a similar system of beef production, employing silage from corn and the sorghums instead of the roots which are the basis of English feeding. (**715-6**)

CHAPTER XXVIII

RAISING BEEF CATTLE

In establishing a beef breeding herd, one should start with as good foundation cows as possible, in order to secure offspring that will make economical gains, mature early, and yield carcasses with a large percentage of the high-priced cuts of meat. (**718-25**) If possible, well-bred grade cows of one of the beef breeds should be selected. Where this can not be done, a start may be made with selected commoner cows, but the progress will then be less rapid. The cows should come as closely as possible to the recognized beef type and conformation and should be low-set, deep-bodied, broad, and compact, with vigorous constitutions and roomy digestive tracts. A pure-bred bull of good quality should always be used, for only then is it possible to build up a herd which will return the most profit.

There are three general systems of handling beef breeding herds. These are: (1) the "straight beef" method; (2) "baby beef" production; and (3) the "dual-purpose" system. In the first two systems the calves run with their dams until weaned, none of the cows being milked. Cows producing calves intended for baby beef are, however, commonly fed a little more liberally, as is pointed out later. (**818-9**) In the dual-purpose system, which is discussed elsewhere (**792**), beef production is combined more or less with dairying. As the straight-beef method is most generally practiced in the United States, it will be considered first.

788. Feeding beef breeding cows.—Where cows are kept only for raising calves for beef, the cost of their maintenance for an entire year must be charged against the fatted steer. In reducing the cost of beef production it is therefore essential that the breeding herd be maintained as cheaply as possible, yet kept in vigorous breeding condition. Only a breeder of pure bred stock who wishes to keep his herd in somewhat of "show condition" as an advertisement can afford to feed expensive rations to his beef cows.

Cows kept solely for beef production are commonly grazed on pasture during the growing season, the suckling calves running with their dams and no additional feed being given to cows or calves. Usually the pastures thus utilized will be the land least suited to tillage. Where land is high-priced and there is but little waste land for grazing, the herd may often be maintained most cheaply on limited pasturage supplemented by summer silage. (**412**) In the fall the cows can get their living chiefly from feed that might be otherwise wasted, such as stubble or stalk fields and the aftermath on meadows. By a little foresight, the

amount of such cheap feed may be increased by seeding rape or clover in the small grain and rape in the corn fields. Shade should always be supplied the herd at pasture.

The winter feed and care may range from the most intensive system, where the herd is fed in barn or shed with the freedom of exercise paddocks, to the practice yet followed in some of the grazing districts of the West, where the only feed is that furnished by the winter range on which the grass has been allowed to grow up and mature. However, bitter experience has taught the western stockman that he must provide against winter's rigors by having available a supply of feed to supplement the range.

The ranchman should provide cheap insurance against feed shortage in snow-bound winters and also summers when the range is parched by drought, by growing sorghums, sunflowers, or other suitable silage crops and preserving the forage in pit silos at spots convenient for watering and feeding. By this means feed may be carried over from seasons of good rainfall to times of need.

In winter the herd may be maintained entirely on roughage when legume hay is available, or on carbonaceous roughages with enough of some such protein-rich concentrate as cottonseed or linseed meal to balance the ration. They should not be allowed to run down in flesh, else they will be unable to produce vigorous calves and nourish them with a good flow of milk. If they go into the winter in poor condition, due to a shortage of feed on pasture, a little grain may be needed to get them into fair condition before calving. Experienced beef producers know that the best calf crop is apt to be secured from cows kept in only fair condition on a properly balanced ration, rather than from cows which are fat. Too liberal feeding of grain is not only extravagant but also is apt to prove actually injurious. (**90, 121**)

In feeding beef breeding cows it should always be borne in mind that to secure thrifty, vigorous offspring it is essential that the cows receive enough protein and plenty of mineral matter, especially calcium and phosphorus. A lack of these nutrients, particularly of calcium, may cause weak or even dead offspring, as has been pointed out in earlier chapters. (**98**)

If alfalfa, clover, or other legume hay forms a considerable part of the roughage, there will be no shortage of protein, calcium, or phosphorus. There should also be no lack of calcium if corn forage is used as the main roughage, unless the soil on which it is grown is very low in this element. However, if straw from the cereals is the chief feed, supplemented with a little cottonseed or linseed meal, there is danger of a lack of calcium. To such rations there should be added 2 to 3 ounces per head daily of steamed bone meal, finely ground limestone, ground rock phosphate, or wood ashes.

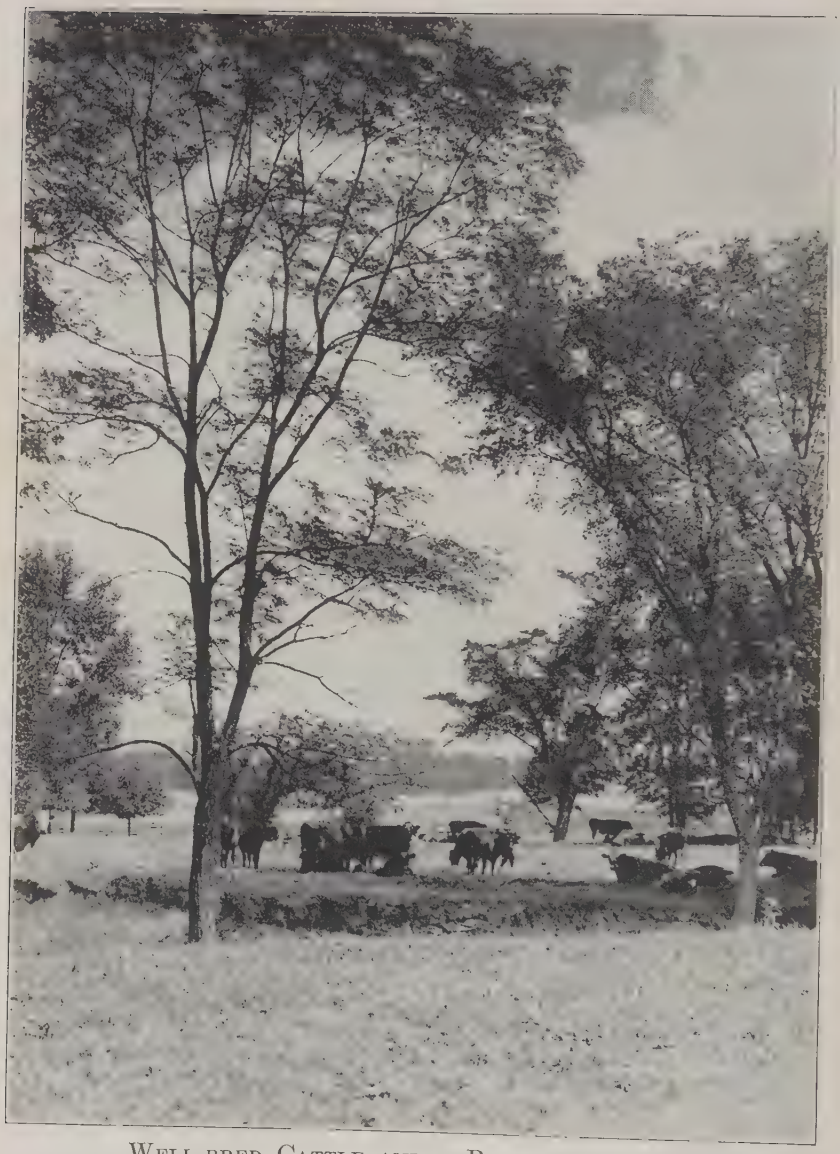
Pure water and plenty of salt should of course always be supplied all cattle. If trouble is experienced from goitre or "big-neck" in calves,

SHADE AND FRESH WATER ARE IMPORTANT ON PASTURE

For all cattle on pasture it is important that shade, fresh water, and salt be provided. Fattening steers nearly ready for market may get rough coats, however, if they spend much time standing in deep water in midsummer to escape the flies.

ABERDEEN ANGUS HERD AT PENNSYLVANIA STATION

Beef breeding cows should be maintained chiefly on cheap feeds in order to keep down the cost of producing the calves, but care must be taken to provide well-balanced rations.



WELL-BRED CATTLE AND A PROSPEROUS FARM

What single-crop, grain-growing farm can furnish a scene of such beauty as this? Sleek, contented cattle; fertile fields; and well-kept fences.

this may be prevented by administering iodine, as has been pointed out previously. (**101, 574**)

If one is in doubt as to whether the ration he intends to feed his breeding cows is balanced, he should calculate the dry matter, digestible crude protein, and total digestible nutrients in it and see how it corresponds with the Morrison feeding standards for beef breeding cows, which are based on recent trials at American experiment stations. (Appendix Table V.) If the ration does not contain the minimum amount of digestible crude protein there advised (0.7 lb. per 1,000 lbs. live weight), enough of some protein-rich supplement should be added to balance the ration. When the cows go into winter in good flesh, the amount of total digestible nutrients may fall slightly below the minimum in the standard in the case of mature cows. On such a ration, however, the cows will probably lose in weight slightly during the winter. Cows which are not yet mature should be fed a little more liberally than full-grown ones, as they need additional nutrients to provide for growth. Cows nursing calves in winter naturally require more feed than those which are dry.

789. Corn belt rations for wintering beef cows.—Thruout the corn belt, the corn plant should furnish much of the roughage for the breeding herd. This may be fed, ears and all, as corn silage or dry corn fodder, or the ears may be removed and the stover fed as dry stover or as corn stover silage.

Corn silage is a more economical feed than dry corn fodder, for it is consumed with less waste and will maintain the cows in better condition.[1] Trials covering 6 years at the Pennsylvania Station, which are summarized later (**791**), show that beef cows may be maintained in satisfactory condition on 50 to 60 lbs. of corn silage per head daily with 1 lb. of cottonseed or linseed meal to balance the ration. In experiments by Rusk at the Illinois Station[2] cows have been maintained in fair condition on only about 40 lbs. of corn silage with 1 lb. of cottonseed or linseed meal. Tho the cows did not carry as much flesh as many breeders would desire, their health was not injured and they produced vigorous calves.

If corn or sorghum silage is fed with 4 to 5 lbs. of alfalfa hay or 5 to 6 lbs. of clover hay, these feeds alone will make an excellent ration, and it will not be necessary to add any protein-rich concentrate. McCampbell of the Kansas Station[3] found that 3.5 lbs. of alfalfa hay was about equal to 1 lb. of cottonseed or linseed meal as a protein supplement for beef breeding cows.

Unless corn grain is low in price, corn silage from well eared corn is rather an expensive feed for maintaining beef breeding cows. Moreover, it is unnecessarily rich in corn grain for the requirements of such animals, whose main need is heat for maintaining the body temperature,

[1]Mumford, Ill. Bul. 111.

[2]Information to the authors.

[3]Hays, Kans. Branch Station, Rpt. of Progress of Beef Cattle Expts., 1919-20.

rather than net energy for productive purposes. (90) Rusk has therefore carried on extensive experiments at the Illinois Station[4] to find whether beef cows can be maintained chiefly on corn stover silage (silage from field cured fodder from which the ears have been husked). In these trials a ration of a little over 60 lbs. corn stover silage and 1 lb. of cottonseed or linseed meal maintained cows in rather spare condition at a cost less than one-third as great as when corn silage containing the ears was used. In a trial by Bohstedt at the Ohio Station[5] corn stover silage was worth less than half as much per ton as normal corn silage for maintaining beef breeding cows in winter. In ensiling corn stover the precautions mentioned in an earlier chapter must be observed to secure a good quality of feed. (300)

Corn stover is not as efficient a feed as properly preserved corn stover silage, for the latter is more palatable and is consumed with less waste. However, dry corn stover is often one of the most economical feeds for beef cows on farms where it can not be readily ensiled. Bright oat or barley straw can also serve as a considerable part of the rations for wintering such cattle. If these feeds are combined with legume hays, no concentrates need be fed. About 5 to 10 lbs. of alfalfa or clover hay, with 10 to 15 lbs. of corn stover or straw (about all they will eat) will provide satisfactory rations for mature beef cows. Stover or straw may be fed with a half allowance of silage (25 to 30 lbs. per head daily) and 1 lb. of such a protein-rich supplement as cottonseed or linseed meal.

Corn stover proved more valuable, ton for ton, than mixed hay or oat straw in a trial by Tomhave and Hultz at the Pennsylvania Station[6] in which 1,100 to 1,200-lb. beef cows were wintered on rations of 30 lbs. corn silage and 1 lb. of cottonseed meal, with these dry roughages in addition.

790. Winter rations for beef cows in other sections.—In the alfalfa districts of the West, beef cows can be carried thru the winter on alfalfa hay alone. However, usually they may be maintained more economically if some lower grade roughage, such as straw or stover, is fed as part of the ration. Arnett found in trials at the Montana Station[7] that while cows maintained their weights better on 10 lbs. of hay a day plus all the oat and barley straw they would eat, than when fed only 5 lbs. of hay with the straw, the difference in the strength and condition was not sufficient to warrant the heavier feeding of hay. Even wheat straw, which is of lower feeding value than oat or barley straw, may be utilized for wintering beef cows or stocker steers.

Good straw can be used as the only feed for wintering mature breeding cattle in mild winters and when the cattle are fat in the fall, tho they lose weight on such a ration. Trials by Arnett and by McCampbell at the Kansas Station[8] show that if 1 to 2 lbs. per head daily of cottonseed

[4]Hoard's Dairyman, 57, 1919, pp. 1106-7.
[5]Information to the authors.
[6]Information to the authors.
[7]Mont. Cir. 85.
[8]Fort Hays, Kansas Station, Rpt. of Progress, Livestock Expts., 1920-21.

or linseed meal is added, better results will be secured, as this will balance the ration. For safety, it is also best to add to such rations a mineral supplement supplying calcium. (788)

In the southwestern states the sorghums furnish cheap roughage for beef cattle. Trials at the Kansas Station[9] by Cochel and later by McCampbell show that stover or fodder from the sorghums, with wheat straw and 1 to 2 lbs. of protein-rich supplements, will carry beef cows thru the winter in satisfactory condition. Ensiling sorghum forage increases its value, just as with corn forage. For example, McCampbell found sweet sorghum silage a much more economical feed than dry sorghum fodder. In another trial, which has already been mentioned (771), an acre of kafir stover made into silage after the heads had been removed was equal in feeding value to 2.2 acres of dry kafir stover. Silage from the sorghums should of course be fed with some protein-rich feed to balance the ration.

In the cotton belt the beef herd should likewise be maintained just as largely as possible on feeds which would otherwise be wasted. For example, in a trial by Gayle at the Mississippi Station[10] beef cows were wintered satisfactorily on silage made from cotton plants seriously damaged by the boll weevil and cut and ensiled while the plants were green. This silage or silage made from a mixture of sorghum and cotton plants gave much better results than the cotton plants cut and cured as hay. For fall and early winter grazing, cowpeas or velvet beans may be grown in the corn fields and the cows turned in after the ear corn has been gathered.

791. Cost of keeping beef breeding cows.—The most extensive investigations yet reported on the cost of maintaining beef breeding cows are those of Tomhave and Severson at the Pennsylvania Station,[11] covering 6 years, 1911 to 1917, inclusive. Each year a lot of 10 pure-bred Shorthorn cows and another of Aberdeen-Angus cows were wintered on corn silage as the only roughage with 1 lb. of cottonseed or linseed meal per head daily in addition. During the winter period, which averaged 154 days, both lots were kept in an open shed or a barn open on one side, with access to an adjacent lot. The rest of the year the breeding cows, suckling calves, and growing stock were on blue-grass pasture and received no additional feed. The average results for the winter period are shown in the table on the next page.

The table shows that the cost of feed and bedding per cow during the winter period was $25.19 for the Shorthorns and $25.26 for the Angus. Adding the cost of the labor and deducting the credit for the manure at the prices indicated, the average net cost of wintering was $20.29 and $20.36, respectively, or an average of $20.32.

[9]Kan. Bul. 198; information to the authors.
[10]Miss. Bul. 181.
[11]Penn. Buls. 138, 150.

Costs of maintaining beef breeding cows

	Shorthorns	Aberdeen-Angus
Av. initial wt., lbs.	1,207	1,169
Av. gain in wt., lbs.	29.1	23.6
Av. ration		
Corn silage, lbs.	61.4	61.6
Supplement, lbs.	1.0	1.0
Bedding per cow for winter, lbs	1,089	1,089
Manure produced per cow, lbs	9,750	9,750
Cost of feed and bedding per cow[1]	$25.19	$25.26
Cost of labor, per cow[2]	2.42	2.42
Credit for manure, per cow[3]	7.32	7.32
Net cost of wintering, per cow	20.29	20.36

[1]Corn silage, $3.50 to $5.00 per ton; supplement, $30 to $44 per ton; bedding $8 per ton.
[2]Manure valued at $1.50 per ton.
[3]Labor charged at $0.15 per hour.

In summer the cows with their calves were kept on blue-grass pastures where the land was too rough for tillage. The cows were allowed 2 acres of pasture each, with 1 acre in addition for each calf over 4 months of age. When grazed at this rate the pastures were not cropped closely in spring, but a surplus of grass was saved for midsummer drought. The cattle were also alternated on the pastures at 2-week intervals to improve the grazing. Valuing the land at $56 an acre, the low price being due to the untillable nature, the pasture charge, including labor, per cow and calf was $7.04.

Other costs of maintaining the cows were: (1) mortality risk on the cows at 1.3 per ct. a year, $1.33; (2) mortality risk on calves, 5 per ct. a year, $2.02; (3) interest on value of cow, $6.00; (4) service of sire, $2.00; and (5) interest and depreciation on equipment, $1.50. This made a total annual cost of maintenance per cow of $40.21, including the costs for the calves up to weaning time, which was at about 9 months of age. With an 80 per ct. calf crop each year, this made the cost of a calf at weaning $50.26.

Tho the costs will vary quite widely in different years and in various sections of the country, depending chiefly on prices of feed and labor, these data will be helpful in estimating the cost under one's own conditions. The cost can generally be reduced somewhat if a large part of the roughage is some cheap material like corn stover, straw, or corn stover silage, instead of corn silage containing the ear corn. (**789**) Also, it aids greatly in cutting down the annual charge for keeping beef breeding cows if the summer feed can be secured from cheap pasture land, unsuited for tillage, as was done in these trials.

In a study of methods of wintering beef cows on 478 corn-belt farms, Cotton[12] found that the average cost of a calf at weaning time under pre-war conditions was $37. On some farms the cost was as low at $25 a calf, while on others it exceeded $50, depending quite largely on the extent to which cheap roughages were used to maintain the cows in winter, in

[12]U. S. D. A. Bul. 615.

place of high-priced concentrates, hay, or silage rich in grain. Many farmers were overfeeding their cows and hence wasting feed, without securing any better calves. One of the greatest wastes was found to be the feeding of unhusked corn fodder, in place of husking out the corn for other stock and feeding the cows the stover, after cutting or shredding it.

Another important factor in reducing the cost of calves is to build up, by selection, a herd of cows which are all regular breeders and satisfactory mothers, producing good yields of milk.

In studies by Sheets and Tuckwiller on a West Virginia[13] farm the annual cost of feed for beef cows fed corn silage, wheat straw, and either mixed hay, soybean hay, or cottonseed meal, was $32.89 with corn silage at $6, wheat straw at $7, mixed hay at $18, soybean hay at $17, and cottonseed meal at $50 per ton.

To study the cost of beef production, a survey was carried on for 3 years (1914-16) by the United States Department of Agriculture[14] on 354 corn-belt farms where cows were kept strictly for raising beef calves. It was found that on the average the following amounts of feed were fed per cow for the winter feeding period of 5½ months: Concentrates, 122 lbs.; hay, 1,900 lbs.; silage, 700 lbs.; straw, 660 lbs.; corn fodder, 0.12 acre; corn stalks, 1.6 acres; corn stover, 0.24 acre; and winter pasture, 4 days. On the average there were 25 cows per farm and nearly an 85 per ct. calf crop was raised on the average.

792. Feeding dual-purpose cows.—Where dual-purpose cows are kept and milked so as to secure dairy products as well as a crop of calves, the cows should be fed the same as dairy cows and the calves raised much like dairy calves. As many dual-purpose cows do not have marked dairy temperament, it is especially important that they be fed strictly according to their actual production, instead of wasting concentrates for which they will not pay at the milk pail. (**647**)

"Double nursing" is a method not followed very extensively, in which about half the cows in the herd nurse 2 calves each and the other half from which the calves have been taken, are milked. For this plan it is essential that all the cows nursing calves be heavy milkers, as otherwise the calves will not make the gains desired.

793. The beef bull.—On the range the bulls run with the cows, but under farm conditions it is best to keep the bull in a paddock or lot separate from the herd except during limited seasons of the year. It will then be possible to keep a record of the dates when the cows are due to calve, and the bull so handled can serve a larger number of cows a year. Thus managed a vigorous bull should serve 25 to 40 cows a year.

The same general principles apply to the feed and care of the beef bull as for the dairy bull, which have already been discussed. (**708**) He should be kept in good, thrifty condition but not fat. Previous to the breeding season he should be well fed, and concentrates should be added

[13]U. S. D. A. Bul. 1,024. [14]U. S. D. A. Farmers' Bul. 1,218.

at other times, as needed, to keep him in condition. If a bull is a "hard keeper" and requires an abnormal amount of feed to keep him in proper flesh, he should be discarded, as he can not be expected to sire cattle which will make economical gains.

The value of using a good pure-bred sire is shown by the fact that calves from a pure-bred bull out of common cows will average 125 lbs. heavier at one year of age than calves from a scrub bull and the same cows, and furthermore they will sell for about 2 cents a pound more as stockers and feeders.[15]

II. Raising Calves for Beef; Veal Production

794. The beef calf.—Under the simplest method of beef production, as on the range, the calves are dropped in the spring and run with their dams during the summer. Under farm conditions some prefer to allow the calves to suck only at stated intervals, 3 times a day at first, and later twice.

Where the calf remains with the dam her udder should, for a time, be stripped night and morning lest neglect bring garget and destroy her usefulness. If the calf is getting too much milk, as shown by scouring, cut off part, remembering that the last drawn portion is the richest in fat, and that richness as well as quantity causes digestive troubles. (117) The greatest danger under this system comes at weaning time, when, if the calf has not been taught to eat solid food, it pines and loses weight. To avoid this, before weaning it should be taught to eat hay and such concentrates as shelled corn, whole oats, wheat bran, and linseed meal. The first departure from this simple and primitive method is putting two calves with each cow, which is feasible where the cow yields a good flow of milk. (792)

Suckling calves should gain 1.75 to 2 lbs., or over, per head daily if their dams give a good flow of milk. At the Pennsylvania Station[16] Hunt fed 3 calves whole milk containing 4.6 per ct. of fat for 161 days. They gained 1.77 lbs. each daily, requiring 8.8 lbs. of whole milk, and 1 lb. of hay and 1 lb. of grain for each pound of growth. Martiny[17] found that from 3.5 to 6 lbs. of new milk was sufficient to produce a pound of gain, live weight, with calves between the first and fifth weeks, while older ones required from 16 to 20 lbs. Linfield of the Utah Station[18] found that up to 14 weeks of age the calf takes less dry matter than the pig for 1 lb. of gain, and after that more, possibly because of the greater amount of roughage then used in the ration. Beach of the Connecticut (Storrs) Station[19] found that calves required 1.03 lbs., lambs 1.08 lbs., and pigs 1.36 lbs. of dry matter in whole milk for each pound of gain made. (117)

[15]Farley, U. S. D. A., Farmers' Bul. 1,073.
[16]Penn. Rpt. 1891.
[17]Die Milch, 2, 1871, pp. 9-15.
[18]Utah. Bul. 57.
[19]Conn. (Storrs) Rpt. 1904, p. 118.

While in some districts it is still best to rear the beef calf on whole milk from dam or pail, over large sections of the country it is now more profitable to sell the fat of the milk in butter or cream and rear the calf on skim milk with proper supplements. This method involves increased labor, skill, and watchfulness on the part of the feeder, but its success has been widely demonstrated. The method to be employed is not different from that already detailed for the rearing of the dairy calf, (**687-93**) except that the beef calf should be forced to more rapid gains thru more liberal feeding.

Calves that fail to thrive when sucking the cow or when fed on rich milk should have their allowance reduced or should be given part skim milk. Care must be taken to prevent scours, and any cases should receive prompt attention. (**703**)

After weaning, growth should be continuous. If the calves are not at pasture, they should be fed plenty of good roughage, with sufficient concentrates to produce the desired gains. As has been shown in the discussion of raising dairy heifers (**704**), for young beef cattle nothing excels good legume hay, rich in protein and bone-building mineral matter. Where this is not available, nitrogenous concentrates should balance the ration.

The majority of beef producers prefer to have calves dropped in the spring, as the cows may then be wintered more cheaply, with less shelter, and less care. Mumford[20] points out that fall calves not fattened as baby beef must be carried thru 2 winters, while spring calves may be sold at the age of 18 to 20 months, after but 1 winter. Some, however, prefer fall calving, reasoning that the cow is in better condition to deliver her calf after the summer on pasture and the fall calf is better able to handle grass, and endure the heat and flies the following season.

795. Veal production.—For producing the highest grade of veal whole milk is the only feed which can be used, for otherwise the desired light-colored flesh and chalk-white fat will not be produced. Furthermore, growth must be pushed as rapidly as possible by liberal feeding and the calf marketed before the carcass takes on any of the coarser character of beef. Such veal commands a high price in some of the European markets, and the butchers are extremely expert in judging whether the calf has received any other feed than whole milk. Only when whole milk has been used exclusively, is the white of the eye of the veal calf free from any yellow tint, and the inside of the eyelids, lips, and nose perfectly white. In this country veal of this kind can be profitably produced only for a special market.

A less expensive method of producing veal is to feed a limited amount of whole milk supplemented by grain, or skim milk may be gradually substituted, as with dairy calves. (**687-8**) With the latter method, considerable skill is necessary to feed the calves so that they will gain rapidly without going off feed.

[20]Beef Production.

In trials by Bechdel at the Pennsylvania Station[21] calves fed whole milk alone for an average of 53 days after birth gained 1.85 lbs. per head daily, required 9.4 lbs. of milk for each pound of gain in weight, and sold for 9.7 cents per pound, live weight. Calves fed on milk substitutes gained only 0.93 lb. per head daily and brought but 5.6 cents a pound, live weight. Feeding only a small amount of milk substitutes in place of milk injured the color of the carcass. He concludes that it is inadvisable to produce veal for the large markets on anything except a straight whole milk ration, due to the inferior quality of the carcass otherwise.

Many farmers in certain districts of Europe make a specialty of producing high class veal. The calves are allowed to suckle their dams or are hand-fed in stalls or crate-like boxes. In Holland, where unusually well-fatted calves are produced, the calves are often kept in small, separate, box-like stalls, with a round hole in the door, thru which the calf sticks its head at meal time. During the rest of the day a cover is kept over the hole, and the calf is in darkness. The stall is kept well bedded so the calf is comfortable at all times. In England the calves are not usually confined in dark quarters, but they are kept quiet by tying them to the manger or by placing each in a separate stall. Often a lump of chalk is kept in the manger to supply calcium and prevent digestive trouble.

Porter[22] writes that during the first day a pint of milk, three times a day, is quite sufficient. An average Shorthorn calf, weighing about 88 lbs. at birth, should not be fed more than 1.5 gallons of milk a day by the end of the first week, 2 gallons by the end of the second week, 2.5 gallons by the end of the third week, and 3 gallons a day by the end of the fourth week. Feeding the milk 3 times a day is advantageous. He states that 4 to 5 weeks is probably as long as it is advisable to feed calves for veal on a dairy farm, or until they have reached 160 lbs. live or 96 lbs. dressed weight. An effort should always be made to have the calves fat at the time veal commands a high price, or the returns will not be great.

III. Growing Beef Cattle

796. Summer care.—Except where calves are being fattened for baby beef (**818**), growing beef cattle are not ordinarily given any feed in addition to good pasture. When necessary to keep the animals growing, additional feed should be supplied, such as summer silage, soiling crops, or specially grown pasture crops. Considerable fall pasturage is furnished by aftermath on meadows or by the stubble fields, especially where a small amount of rape seed is sown with the spring grain.

797. Wintering calves.—Calves should always be kept in vigorous, growing condition during their first winter, but the ration should consist almost entirely of roughage, except for calves to be finished as baby

[21]Penn. Rpt. 1916-17. [22]The Stock Feeder's Companion, 1915, pp. 146-152.

beef. As is pointed out later, these should be fattened as they grow by feeding a liberal ration. It is not economical to feed other calves so heavily that they will become fat, for winter gains are expensive, compared with pasture gains. Furthermore, if cattle carry too much flesh when turned to pasture without grain the following summer, they will make much smaller gains on grass. As calves are increasing rapidly in protein tissues and skeleton, it is important that their rations contain plenty of protein, calcium, and phosphorus.

In the West where alfalfa hay is cheap in price, it is a standard ration for wintering steers, being commonly fed without any grain. In trials by Potter and Withycombe of the Oregon Station[23] steer calves fed 20 lbs. alfalfa hay a head daily, gained 1.14 lbs. and the next winter their daily gain was 1.21 lbs. on 26 lbs. of hay a day. Steer calves fed only 10.3 lbs. alfalfa hay a day at the Kansas Station[24] in trials by McCampbell and Winchester were carried thru the winter in satisfactory condition, gaining 0.45 lb. a day. As yearlings they gained 0.47 lb. a day on a ration of 22.1 lbs. alfalfa hay. Similar results can be secured with hay from other legumes.

If fed as the only roughage, hay from the grasses or dry corn or sorghum fodder or stover is decidedly inferior to legume hay. For example, in a trial by Snyder at the North Platte, Nebraska, Station[25] calves fed alfalfa hay with 2 lbs. per head daily of a mixture of corn and oats gained 1.08 lbs. while others fed prairie or sorghum hay in place of alfalfa gained less than half as much. However, such carbonaceous dry roughages are satisfactory when combined with legume hay. In these trials calves gained practically as fast when fed half prairie or sorghum hay and half alfalfa, as when alfalfa was fed as the only roughage. By thus substituting cheaper roughages for part of the more expensive legume hay, the cost of raising steers can often be materially lessened.

Quite commonly silage from corn or the sorghums is one of the cheapest roughages for wintering steers. In the trials by Potter and Withycombe when silage was added to a ration of alfalfa hay alone for wintering calves or yearlings, it was worth $5 a ton with alfalfa at $8 a ton. Calves fed 10 lbs. silage and 16 lbs. alfalfa hay made the excellent gain of 1.30 lbs. per head daily, and yearlings fed 15 lbs. silage and 23 lbs. alfalfa hay gained 1.39 lbs.

In trials covering 3 years on a West Virginia farm by Sheets and Tuckwiller[26] a winter ration of 12.3 lbs. corn silage and 4.9 lbs. clover hay produced satisfactory gains on steer calves. Including both the winter gains and the gains on pasture the following summer, this ration made nearly as large and considerably cheaper gains than 9.2 lbs. mixed clover and timothy hay plus 2.6 lbs. of concentrates.

When legume hay is not available or is high in price compared with other roughages, silage may be used as the only roughage or it may be

[23]Ore. Bul. 182.
[24]Kan. Cir. 92.
[25]Nebr. Buls. 105, 117.
[26]U. S. D. A. Bul. 1,042.

fed with cheap dry roughages like straw or stover. In such cases about 1 lb. of cottonseed or linseed meal, or an equivalent amount of some other protein-rich concentrate, should be added to balance the ration.

Trials by Cochel and McCampbell at the Kansas Station[27] show that calves may be wintered satisfactorily on silage from corn, kafir, or sweet sorghum, with 1 lb. of cottonseed or linseed meal per head daily in addition. The manner in which cheap roughages may be largely utilized even in wintering calves, when combined with silage, is shown in a 144-day trial by Cochel in which 30 calves fed a ration of 3.3 lbs. wheat straw, 2.3 lbs. corn stover, 2.9 lbs. foxtail and damaged alfalfa hay, 6.8 lbs. kafir silage, and 0.8 lb. of a concentrate mixture, gained 41.8 lbs. each at a daily feed cost of 3.3 cents per head. The total gross cost of wintering the calves was only $5.72 per head, from which should be deducted the value of the manure. In spite of opinions to the contrary, steers fed silage in the winter will make fully as large gains on pasture the following summer as tho fed dry roughage, and often even larger gains.

In the West Virginia trials previously mentioned, cheap and satisfactory gains were secured when calves were fed a winter ration of 12.3 lbs. corn silage, 3.9 lbs. rye hay, and 0.6 lb. cottonseed meal. In these trials the cost of the winter feed was about two-thirds that for the entire year, while most of the gain, on the other hand, was made in summer on pasture. This emphasizes the fact that calves must be wintered economically if profits are to be secured. Concentrates should be fed only when necessary to balance the ration or when the roughages are of such poor quality that the calves would otherwise come thru the winter in too poor condition to make large gains on pasture.

798. Wintering yearlings and 2-year-olds.—Older steers can make even greater use of cheap roughages than calves. Hence, unless grain is very cheap in price, yearlings and 2-year-olds which are to be grazed on pasture without grain the following summer are usually wintered on roughage alone. Of course, a small amount of a protein-rich concentrate like cottonseed or linseed meal should be added, if needed to balance the ration. If the steers are to be finished for an early summer or fall market by feeding them grain or other concentrates in addition to pasture, then some grain is quite commonly fed during the winter, especially just previous to turning on grass.

In trials covering 4 winters at the Missouri Station[28] Waters found that yearling steers wintered on 31.3 lbs. whole corn stover or 23.6 lbs. shredded corn stover lost in weight, while fairly satisfactory gains were made on a ration of 47.4 lbs. corn stover silage. A ration of 13.6 lbs. clover hay and 13.6 lbs. whole corn stover was also satisfactory.

In other trials in which yearlings were fed a limited amount (4 to 6 lbs.) of shelled corn per head daily in addition to various roughages,

[27]Amer. Soc. Anim. Prod., Proceedings, 1915-16, pp. 9-14; Kan. Cir. 92; information to the authors.

[28]Mo. Bul. 75.

Waters secured much poorer gains from timothy, millet, or sorghum hay fed with corn than from clover, alfalfa, or cowpea hay and corn, due to the fact that the former rations were very low in protein. Where the roughage was half corn stover and half clover hay, the gains were good.

Silage from corn or the sorghums is usually an exceedingly economical feed for wintering steers, as it produces good gains at low cost. In trials during 3 years in West Virginia[29] by Sheets and Tuckwiller, yearling steers wintered on 20.0 lbs. corn silage, 5.0 lbs. mixed clover and timothy hay, and 2.5 lbs. wheat straw maintained their weights, while others fed mixed hay and wheat straw lost in weight. During the winter and the following summer the silage-fed steers gained a total of 316 lbs. each at a feed cost of 7.2 cents per lb. gain. The steers wintered on dry feed, as is the common practice in this district, gained only 274 lbs. each during the year, at a cost of 8.6 cents for each pound of gain. On a ration of corn silage, wheat straw, and 1 lb. of cottonseed meal, the gains were the largest and the cost per lb. gain only 6.9 cents.

In 3 trials at the Kentucky Station[30] with steers carried thru the winter and fattened on grass alone the following summer, Good found a ration of 28 lbs. corn silage, 1.5 lbs. cottonseed meal, and what stover or straw the steers would eat, more economical, considering both winter and summer gains, than when dry feed only was used. Corn silage alone, without any protein-rich supplement, was found to be the most economical ration for wintering 2-year-old steers, considering both winter and summer, in trials by Hunt at the Virginia Station.[31] These steers, fed 40 lbs. of silage a head daily, lost 45 lbs. each on the average during the winter, but were in thrifty condition and made large gains on pasture the following summer. Steers fed 1 lb. of cottonseed meal daily in addition to silage more than maintained their weights in winter, but they did not make as large gains on pasture as those fed silage alone in winter. In fact, their total gain was less than for the steers wintered on the unbalanced ration of corn silage alone. In these trials mixed clover and timothy hay proved a better supplementary roughage for silage than either corn stover or straw, doubtless because it was richer in protein.

In the Appalachian region south of Kentucky and Virginia steers are often wintered on rough pasture land on which stock has not been grazed in summer. In trials in western North Carolina,[32] steers pastured on such land in winter maintained their weights better than others fed corn silage alone; or mixed hay alone; or a ration of corn silage, straw, and stover. It was found that 2 acres of mountainous cut-over land properly seeded would carry a steer over winter and that 3 acres additional would provide good summer pasture.

799. Raising beef heifers; age to breed.—It is very important that the heifers retained for the breeding herd make good growth and develop-

[29]U. S. D. A. Bul. 870. [30]Ky. Cir. 75. [31]Va. Bul. 215.
[32]Curtis, Farley, and Peden, N. C. Bul. 243; U. S. D. A. Bul. 954.

ment prior to dropping their first calves. The strain of milk production then comes upon them and they will usually lose in weight and make small growth during the first lactation period. In winter the heifers should therefore be fed somewhat more liberally than is necessary for steers. Plenty of protein and mineral matter should always be provided to ensure proper development.

With good legume hay and corn silage for roughage, little or no grain is necessary. If lower grade roughages are used, enough concentrates should be added to keep them in thrifty growing condition at all times. In trials at the Pennsylvania Station[33] Tomhave and Severson had good results when heifers were wintered on corn silage as the only roughage, with 3 lbs. of cottonseed meal daily per 1,000 lbs. live weight to balance the ration. Rations of 20 lbs. kafir silage, 1 lb. wheat straw, and either 3 lbs. alfalfa hay or 1 to 2 lbs. of cottonseed meal were satisfactory for wintering 630-lb. heifers in a trial by Blizzard at the Oklahoma Station.[34]

Under farm conditions beef heifers are usually bred to calve when 24 to 30 months old. Tomhave and Severson found that when heifers dropped their first calves prior to 30 months of age they remained permanently stunted unless allowed 14 to 15 months between the first calving and the second.

In the range sections of the country it has been a problem for the cattlemen to maintain sufficient size in their breeding herds. This is due not only to animals being stunted by feed shortage in winter but also to the effects of early breeding. In an extensive investigation at the Hays, Kansas, Branch Station[35] by McCampbell one group of heifers has been wintered on roughage alone up to the first calving, with pasture in summer, while another has been wintered on a liberal ration of roughage plus grain. Half of each group was bred to calve when 2 years old, and the rest at 3 years. When early calving was combined with a winter ration of roughage alone, as is a common practice in this district, not only did the heifers fail to reach as large size as the others, but the average weight of their calves at weaning time for 3 consecutive years was only 348 lbs.

Compared with this, the average weaning weight of the calves from the heifers raised similarly, but calving as 3-year-olds, was 405 lbs. The indications were also that a considerable percentage of these heifers calving as 2-year-olds and raised on roughage alone later became nonbreeders. Raising the heifers on a liberal allowance of grain in winter largely prevented the ill-effects of early breeding, but this method was expensive under range conditions. McCampbell concludes that the development of heifers without grain, and breeding them to drop their first calves at 3 years of age, is the most practical under range and semi-range conditions.

[33]Penn. Buls. 138, 150. [34]Okla. Rpt. 1920, p. 24.
[35]Amer. Soc. Anim. Prod., Proceedings, 1920, pp. 12-14.

CHAPTER XXIX

COUNSEL IN THE FEED LOT

The years of 1920 and 1921 will not soon be forgotten by cattlemen, for in most cases they suffered unprecedented losses on their feeding operations, due to the fact that finished cattle sold at a much lower price than the same animals had cost before fattening. These losses were one of the unfortunate products of the world-wide economic depression brought about by the recent war. Fortunately, the horizon now looks brighter for the beef producer. It is reasonable to expect that in the future, as in the past, good profits will be made, over a term of years, by the man who intelligently plans his feeding operations.

The common type of beef production in the corn belt—the fattening of purchased feeder cattle—is much more speculative in nature than most ventures in animal husbandry. To secure good profits it is therefore especially necessary that the several factors which make for success in the enterprise be kept clearly in mind. These are accordingly discussed in the following paragraphs.

800. Rations for fattening cattle.—The numerous trials reviewed in the preceding chapters show forcefully that greatly increased profits are secured when fattening cattle are fed properly balanced rations. A cattleman is therefore foolish indeed if, thru force of habit, he continues to finish his steers on rations which experiments and also practical experience have shown to be uneconomical. Whenever there is any question as to whether a ration is balanced, it will take but a short time to compute the approximate amounts of dry matter, digestible crude protein, and total digestible nutrients it contains and see how closely the ration meets the recommendations of modern feeding standards. (Appendix Table V.) The time it takes to work out suitable and economical balanced rations is commonly the most profitably spent of all the year. The general principles which should be followed in computing balanced rations for cattle are fully discussed in previous paragraphs. (**190, 710**)

In determining which feeds are most economical under local conditions, it will be helpful to figure out the actual cost per pound of digestible crude protein and total digestible nutrients in those feeds which seem most suitable, as has been explained previously. By making a study of this sort and also considering the results which have actually been secured with various rations in practical feeding trials, as summarized in Chapter XXVII, one may readily determine just what feeds will be most profitable for him to use.

801. Equipment for feeding cattle.—Many feeders do not realize that providing proper equipment is an important factor in securing profits in cattle feeding. The character of shelter advisable for winter feeding will depend on the climate. As has been pointed out previously, expensive shelter is not necessary for fattening cattle, even in the northern states. (**727**) All that is needed, even where the winters are cold, is a shed, sheltered from prevailing winds, and opening on the south into well-drained feed lots. Where the soil and climate are such that the feed lots often become a sea of mud in winter or early spring, paving them with concrete is an economy. Not only do the steers make larger and more economical gains, but also much loss of manure is prevented. (**731**)

There should be sufficient space in feed lots and shed for the comfort of the steers, a safe average being 90 to 100 square feet per head, including the area of the shed, which should provide 20 to 25 square feet for each steer. Cattle of the same age, or at least those of equal size and strength, should be fed in the same lot. Weak animals, and those unable to crowd to the feed trough and get their share, should be placed where they can eat in quiet. From 2.5 to 3 feet of feed racks or bunks should be provided per steer, so there will not be undue crowding at meal time. Some feeders use combination feed racks for grain and roughage, while others prefer a separate rack for hay and a bunk or flat trough for silage and grain. Feed racks and bunks should always be cleaned after each feeding. As is emphasized later in this chapter, fresh water and salt should always be provided. (**805-6**)

802. Getting cattle on feed.—Cattle which are not acustomed to corn or other concentrates must be started on feed gradually or serious digestive trouble may result. From the start they should be given all the good roughage, such as hay and silage, they will clean up. For animals to be fattened on a full feed of grain, a safe plan is to feed them in addition 2 to 3 lbs. of corn or other grain at first, and then increase the allowance 1 lb. a day or less until about 10 lbs. daily is fed. After this the grain should be increased even more gradually, say 1 lb. every third day until they are on full feed.

When cottonseed meal or linseed meal is fed to balance the ration, one-half to one pound per head daily may be fed at first, and the allowance gradually increased one-quarter of a pound daily per steer until the full amount needed to balance the ration is supplied.

803. Frequency and method of feeding.—Most cattlemen feed concentrates and roughage twice a day to fattening steers not on pasture. As pointed out later, it is important that the feeding be at the same time each day. Usually the grain is fed first and then the silage, after the grain is cleaned up. Hay or other dry roughage is fed in suitable racks, also twice daily. So that each steer will get his share of any protein-rich supplement, like cottonseed meal or linseed meal, it should be mixed with the corn or other grain or else with the silage.

Commonly when concentrates are fed cattle on pasture, they are sup-

plied but once a day, largely as a matter of convenience, since the stock may be grazing on a tract at some distance from the farmstead.

804. Pigs following steers.—Whenever cattle are fed ear corn, shelled corn or corn silage, pigs should be kept with them to utilize the unmasticated and undigested corn in the droppings. The margin in cattle feeding is frequently so narrow that the gains made by the pigs return the only profit. It is therefore essential that pigs be provided to follow the cattle, except when they are fattened on a ration from which the pigs would not secure much waste feed, such as a ration of ground grain and hay without silage, or a ration of cottonseed meal and cottonseed hulls.

The number of pigs per steer varies with the kind of feed and the age of the cattle being fed. Enough should be provided to utilize the waste feed fully. The range is 1 to 3 pigs per steer on snapped corn, 1 to 2 per steer on husked ear corn, about 1 per steer on shelled corn, and 1 pig to 2 or 3 steers on crushed or ground corn. The younger the steers, the better they masticate and utilize their feed and the smaller are the gains made by the pigs following. The best pigs for following cattle weigh from 50 to 150 lbs. and when they become fat they should be replaced. Any extra grain given the pigs to ensure their making satisfactory gains should be fed in nearby separate pens before the cattle are fed, so that the pigs will not crowd around the feed troughs or under the wagon and team when the cattle are being fed. It pays to feed pigs following steers 0.2 to 0.3 lb. per head daily of tankage, or an equivalent amount of other protein-rich feeds, to balance the ration.

805. Water.—Fattening cattle should have an abundant supply of pure water at all times. During winter in the northern states the water in the tanks or troughs should be kept from freezing by using suitable heaters, but there is no advantage otherwise in warming water for fattening steers.[1] Separate water troughs should be provided for pigs running with the steers. While it is best to have water before cattle at all times, they quite readily adapt themselves to taking a fill once daily. The water provision should be not less than 10 gallons per head daily for 2-year-old steers.

806. Salt.—Animals fed large quantities of rich nutritious food, such as fattening steers receive, show a strong desire for salt, and this craving should be reasonably satisfied. Whether granular salt, rock salt, or salt blocks should be supplied is merely a matter of convenience. It is probably best to keep salt before the cattle at all times, tho some secure excellent results when they give salt only once or twice a week. As in other matters of feeding, habit is important, and a plan once adopted should be followed without deviation.

There is but little definite information on the amount of salt required by beef cattle. During 5 years Evvard found in trials at the Iowa Station[2] that 2-year-old steers fattened on typical corn-belt rations, including corn silage, and allowed free access to block salt, consumed

[1]Potter and Withycombe, Ore. Bul. 183. [2]Breeder's Gazette, 76, 1919, p. 307.

just about one-third ounce of salt per head daily. The gains of the steers each year were very satisfactory, showing this amount of salt to be ample under these particular conditions, tho it is considerably smaller than previously recommended by European authorities.

In a trial carried on by the Kansas Station[3] it was found that during the summer yearling and 2-year-old steers on pasture licked about 1 ounce of salt per head daily from salt blocks placed in the pasture. Nearly an equal amount was lost thru weathering of the blocks, which were not under a shelter. During the first part of the pasture season the cattle licked nearly twice as much salt as was consumed per month later on in summer.

807. Variations in weight.—Fattening steers show surprising variations in weight from day to day, and even from week to week. Even when weighed at the same time on consecutive days and under apparently similar conditions, the weight of a steer on any particular day may vary 20 to 40 lbs., and sometimes even more, from the weight on the previous day.

These variations show how difficult it is to know the true weight of a steer at any given time. Experiment stations now quite generally weigh all experimental animals for 3 successive days at the beginning and end of feeding trials, taking the average as the true weight of the animal on the second day. It has been suggested that the variations follow somewhat the amount of water drunk from day to day, but this explanation does not always seem sufficient. It seems more generally due to the irregular movement of the contents of the digestive tract, which movement is influenced by changes in the character and quantity of the food consumed, the exercise or confinement enforced, and the weather.

808. Preparing for shipment; shrinkage.—Unless cattle are shipped under proper conditions, the shrinkage between their weights at home and the selling weights on the market may be so large that it will eat up no small part of the profits. On the average the shrinkage between the loading weights and the sale weights at the stockyards of either range cattle or fat cattle in transit 36 hours or less is 3 to 4 per ct.; when in transit 70 hours or over the shrinkage is 5 to 6 per ct. of their live weight.[4] In addition there will be a slight shrinkage in weight from the feed lot to the loading station. Silage-fed cattle show a larger gross shrinkage but usually fill so well at market that the net shrinkage is even lower than with cattle fed no silage. Pulp-fed cattle shrink more than any other class. The difference in shrinkage between cows and steers is not as great as is ordinarily supposed, tho cows shrink somewhat less than steers of the same weight and degree of finish. Well fattened animals shrink less than those in thin flesh. For example, canner cows shrink more proportionately than finished stock.

If cattle are continued on succulent feeds, such as grass, silage, or beet pulp up to the time of loading, the shrinkage is great. It is therefore

[3]Hensel, Breeder's Gazette, 80, 1921, p. 181. [4]Ward, U. S. D. A., Bul. 25.

WARM SHELTER IS NOT NEEDED FOR FATTENING STEERS

Heavily-fed fattening steers thrive best with no shelter except an open shed, but animals being carried thru the winter on scanty rations need warmer quarters.

QUIET IS HIGHLY IMPORTANT IN MAKING BEEF

Cattle which "eat and lie down" make much more economical gains than those which are restless and active. Most of the steers in this Nebraska feed lot have eaten their fill and are lying down contentedly, chewing their cuds.

PASTURE GAINS ARE CHEAP GAINS

Bluegrass is the most common pasture for beef cattle in the North, but clover makes excellent pasture, if care is taken to avoid bloat.

MEAL TIME IN A CORN-BELT FEED LOT

The steers are being fattened on an efficient well-balanced ration, including corn grain, corn silage, and a protein-rich supplement. Where cattle are fed ear corn, shelled corn, or well-eared corn silage, pigs should follow them to utilize the waste grain.

best about two days before shipping to substitute other less washy feeds for the succulence. However, the change should not be too abrupt, or the animals may be thrown off feed.

Some shippers think that by withholding water from the cattle or feeding them salt, they can get them to drink a large amount of water when they reach the stock yards, and thus take on a heavy "fill." Such a practice is not only cruel, but it deceives no one but the shipper himself. Buyers both of fat cattle and of feeders can easily recognize animals which have taken on an abnormal fill and they will discriminate against them by offering a lower price per hundred weight.

Before the cattle are loaded, the car should always be well bedded. If different kinds of live stock are put in the same car, they should be tied securely. For feeding in transit nothing is better than good hay, for it is easily digested and is not apt to throw the cattle off feed.

Slow, rough runs to market naturally increase the shrink. For a long journey the common method of unloading for feed, water, and rest is better than the use of "feed and water" cars. When cattle reach the market just before being sold, the fill is small, but when they arrive the afternoon of the day before. or about daylight of the sale day, they generally take a good fill.

809. Cattle fattening requires business judgment.—In fattening cattle, even more than in other lines of animal husbandry, good business judgment must be exercised, or the venture is apt to result in loss. The following are some of the important points to be observed by one entering the cattle feeding business.[5]

Before purchasing feeders one should estimate the quantity of feeds on hand and their market prices. From this he can determine how many and what class of cattle he had best buy to consume the feed. He should then study the market reports and by a little figuring can find out about how much his feeders will cost, including the expense of getting them to his feed lot. Then he can figure out approximately how much the gains will cost him, by using the data in the preceding chapters, in which are shown the actual results on many typical rations. He can then readily compute the necessary selling price he must secure to break even, of course taking into consideration the marketing costs. If the out-look for a profit does not seem reasonably good, it is usually not best to buy just at that time.

Feeders should always be chosen which seem to offer the best opportunity for profit. It is an old adage among stockmen that "cattle bought right are more than half sold." A man may be a skillful feeder and lose money year after year because of poor judgment in buying. The beginner should hire some experienced cattleman to purchase animals that will best suit his needs, or deal with a reliable commission firm that is acquainted with his conditions. If choice feeders are commanding a high premium in the market over commoner animals, and it does not

[5]Largely from Cotton and Ward, U. S. Dept. Agr. Farmers' Bul. 588.

seem probable that the premium will be correspondingly large for the cattle of better quality when they are fattened, the commoner grade had better be purchased. On the other hand, the fact must always be taken into consideration that the better-bred animals will usually make somewhat more economical gains.

By following the various market reports for preceding years, one can tell approximately when his cattle can be marketed to greatest advantage. The steers should then be fed so as to be finished at that time. When the steers are ready for market, it is usually not advisable to hold them for better prices unless they continue to make gains at a reasonable cost. The extra feed consumed by finished cattle will soon more than offset any ordinary increase in price that may be obtained. When the cattle are almost finished, the owner should watch the market reports and find out from his commission man the best date for shipment.

810. Regularity and quiet.—On these important points in fattening cattle, Mumford writes:[6]

"As soon as the fattening process begins, the cattle should be fed at certain hours and in the same way. This cannot be varied 15 minutes without some detriment to the cattle. The extent of injury will depend upon the frequency and extent of irregularity. . .The even-tempered attendant who is quiet in manner and movement invariably proves more satisfactory than the erratic, bustling, noisy one. The cattle soon learn to have confidence in the former and welcome his coming among them, while they are always suspicious of the latter, never feeling quite at ease when he is in sight. Under the management of the former, the cattle become tame and quiet, even tho more or less wild at the outset; while under the latter, wild cattle become wilder and tame cattle become timid. The writer has observed a wide difference in practice among feeders as to their manner of approaching fattening steers. Some are brusque in manner, rushing up to the steers and scaring them up quickly, while other (and I am bound to say more successful) feeders approach the cattle with the greatest care and consideration, getting the cattle up, if at all, as quietly as possible. Pastures for cattle in quiet, secluded places are more valuable for fattening cattle than are those adjacent to the public roads or adjoining pastures where horses or breeding cattle run." (112)

811. The eye of the master.—There is so much truth in the old saying, "The eye of the master fattens his cattle," that this adage has appeared on the title page of each edition of this book for the past 24 years. In all phases of animal husbandry the discernment of a good stockman is essential for real success. Being versed in the science of stock feeding is not enough. For the greatest profits not only must one feed his stock economical and well-balanced rations, but also he must have the watchful eye and good judgment of a true stockman. Fortunately, the successful methods of live stock care and management are not complicated

[6]Beef Production, pp. 92-3.

but are in reality relatively simple and easily understood. Therefore, practically anyone who likes live stock and is willing to give intelligent attention to the necessary details in animal husbandry can succeed.

Experience counts for much in stock feeding. Many an experienced stockman can carry steers thru the fattening period without getting them once "off feed," but yet can not well describe to others just why he is so successful. In general, when steers are to be full fed on grain, they should be supplied all they will readily consume at each feeding, after they have been gradually brought onto feed. Any feed left in the feed bunk or manger should be cleaned out before the next feeding, for it will not usually be eaten by the cattle afterwards, but it will spoil and contaminate the fresh feed put in later.

Many experienced feeders follow the rule, "Keep the feed always a little better than the cattle." As has been shown (**735**), this means that the preparation of the feed is increased as the fattening progresses. Likewise as the animal advances in flesh there is greater benefit from adding a nitrogenous concentrate, such as cottonseed or linseed meal, to a ration which is already fairly well balanced.

Scouring, the bane of the stock feeder, should be carefully avoided, since a single day's laxness may cut off a week's gain. This trouble is generally brought on by over-feeding, by unwholesome food, or by a faulty ration. Over-feeding comes from a desire of the attendant to push his cattle to better gains, or from carelessness and irregularity in measuring out the feed supply. The ideal stockman has a quick discernment which takes in every animal in the feed lot at a glance, and a quiet judgment which guides the hand in dealing out feed ample for the wants of all, but not a pound excess.

The droppings of the steers are an excellent index of the progress of fattening. While they should never be hard, they should still be thick enough to "pile up" and have that unctuous appearance which indicates a healthy action of the liver. There is an odor from the droppings of thrifty, well-fed steers known and quickly recognized by every good feeder. Thin droppings and those with a sour smell indicate something wrong in the feed yard. The conduct of the steer is a further guide in marking the progress of fattening. The manner in which he approaches the feed box; his quiet pose while ruminating and audible breathing when lying down, showing the lungs cramped by the well-filled paunch; the quiet eye which stands full from the fattening socket; the oily coat,—all are points that awaken the interest, admiration, and satisfaction of the successful feeder.

II. Methods of Beef Production

812. Fattening cattle on pasture.—Whether it will be most profitable to fatten cattle during the winter and spring in the dry lot or to fatten them in summer on pasture will depend, first of all, on the relative cost

of pasturage compared with hay, silage, and other feeds. In those beef producing sections where there is considerable land which is too hilly or rough for tillage, usually many cattle will be fattened on pasture for market in the late summer or early fall. In the grazing regions of the West, where grain is high in price compared with pasture, the steers are commonly sold at the close of the pasture season. Then, if the grass has been good, many are fat enough to be sold as killers, while most of the rest will be fattened further in feed lots in the corn belt or elsewhere where grain is cheaper in price. On farms where land is high-priced and there is little waste land, cattle are usually fattened in the dry lot, since under these conditions corn silage is cheaper than pasturage, for it furnishes much more feed per acre. For example, in a trial at the Nebraska Station[7] steers fed corn silage, corn grain, and a supplement in a dry lot made just as large gains as others fed the same concentrates on pasture, and only one-fourth as much land was needed to produce the silage as was required for pasture. Fully 90 per ct. of the cattle fattened in the corn belt are dry-lot fed and are marketed before July 1st.[8]

813. Summer vs. winter feeding.—Fattening cattle on pasture has several advantages over dry lot feeding.[9] First of all, gains on pasture require less grain than winter gains. Steers on pasture can be made prime on corn and grass with greater certainty, more uniformity, and smaller use of expensive supplements like linseed and cottonseed meal. Less labor is required, for only grain is fed, and there is no roughage to handle. Furthermore, the steers are usually fed but once daily and also the manure is scattered by the cattle themselves. Another advantage is the fact that hogs following steers fed corn on pasture make larger gains and return more profit, with a lower death rate than when following steers fattened in the winter.

Fattening cattle on pasture was compared with winter dry-lot feeding in 3 summer and 5 winter trials by Waters at the Missouri Station[10] with the results shown in the following table:

	Summer	Winter
Number of animals	88	105
Average length of feeding period, days	209	107
Concentrates per 100 lbs. of gain, lbs	814	999
Roughage per 100 lbs. of gain, lbs	grass	382
Average daily gain per steer, lbs	2.37	2.13

Because of the longer feeding period the summer-fed cattle were much fatter than those fed in winter. Despite this the summer gains were made on 18.5 per ct. less grain.

Mumford and Hall of the Illinois Station,[11] from extensive correspondence with feeders of their state, concluded that a bushel of corn will produce:

[7]Bliss and Lee, Nebr. Rpt. 1913.
[8]Black, U. S. Dept. Agr. Farmers' Bul. 1218.
[9]Largely adapted from Waters, Mo. Bul. 76.
[10]Mo. Bul. 76.
[11]Ill. Cirs. 79, 88.

	Gain in winter feed lot	Gain in summer on pasture
With calves	8.9 pounds	10.0 pounds
With yearlings	6.5 pounds	7.6 pounds
With 2-year olds	5.4 pounds	6.8 pounds

They found that cattlemen estimate the daily increase per head of steers during the grazing season at 1.66 lbs. for yearling and 1.87 lbs. for 2-year-olds.

Waters of the Missouri Station,[12] gathering statistics from more than 1,000 successful cattlemen in Missouri, Illinois, and Iowa, found the average gains from cattle pastured without grain were as follows for the 6-months period, May 1 to November 1:

Average gain of steers for 6-months season on grass

State	By yearlings		By 2-year-olds	
	Per month Lbs.	Per season Lbs.	Per month Lbs.	Per season Lbs.
Missouri	47	282	53	318
Iowa	48	288	52	312
Illinois	45	270	52	312

By taking the usual rental charge for pasture in a given region, the approximate cost of gains on pasture may be readily determined. For example, assuming a pasture charge for yearlings of $1.50 per month, their gains would cost approximately $3.20 per 100 lbs., while the 2-year-olds at a pasture charge of $2 per month would put on gains costing only about $3.80 per 100 lbs. When we consider that gains made by steers in winter cost from $6 to $10 per 100 lbs. for feed alone, the economy of pasture in fattening cattle is apparent.

Skinner and Cochel of the Indiana Station[13] found thru extensive inquiry that in Indiana during summer feeding each grain-fed steer grazed over 1.1 acres of land on the average. Where no grain was given, each steer grazed over about 2 acres.

Lloyd of the Mississippi Station[14] reports that 2-year-old heifers, fed a light ration during the winter, when turned to pasture gained 1.3 lbs. each daily for 178 days on pasture alone. Steers of the same age, thin in flesh when turned to pasture, made daily gains of 1.4 lbs. for 178 days, while those full fed the previous winter gained but 0.8 lb. each day during 158 days.

814. Feeding concentrates on pasture.—When cattle are finished on pasture, no concentrates at all may be fed, a small allowance may be given during the entire pasture period, concentrates may be fed during only the last few weeks, or an unlimited allowance of grain may be given thruout the entire period. It will usually pay to feed some grain in addition to pasture except under range conditions and in certain districts, as in the bluegrass regions of Virginia and adjacent states and

[12]Mo. Cir. 24. [13]Ind. Cir. 12. [14]Miss. Rpt. 1903.

also in southwestern Wisconsin, where the pastures are unusually nutritious.

The gains on grass alone will commonly be cheaper than where grain is fed in addition, but the cheapness of the gains may be more than offset if the cattle do not reach a good finish and hence are sold as feeders at a price which is low enough to allow the buyer a profit in fitting them for market. Usually not over 10 to 15 lbs. of corn or other concentrates are fed per head daily to cattle being fattened on pasture, unless it is desired to crowd them for an early market.

In the northern states the concentrate most commonly fed on pasture is corn, with perhaps a small amount of a protein-rich supplement in addition. In the South, however, quite commonly cottonseed cake or meal is the cheapest concentrate available, and therefore an allowance of 3 to 4 lbs. per head daily is often fed to cattle on pasture. This materially increases the rate of gains made by the cattle, causes them to reach a higher finish, and enables them to be marketed before the rush of grass-finished cattle occurs. In trials by Ward, Gray, and Lloyd in Alabama and Mississippi,[15] feeding such an allowance of cottonseed cake on pasture usually increased the profit over fattening cattle on pasture alone, without considering the fertility added to the pasture fields by the feeding of the cottonseed cake.

815. Feeding supplements with corn on grass pasture.—Since immature grass, such as is usually eaten by grazing animals, is much richer in protein than grass at the stage when cut for hay, corn and bluegrass pasture alone make a fairly well-balanced ration for the fattening steer. Extensive experiments by Mumford at the Missouri Station[16] show, however, that it is usually advisable to add some protein-rich supplement during the last of the feeding period to keep the steers from going off feed and making smaller gains. In these trials separate lots of yearlings, 2-year-olds, and 3-year-olds were fed corn alone on bluegrass pasture, while other lots were fed a small allowance of linseed meal, cottonseed meal or gluten feed in addition to corn and pasture. Adding a supplement slightly increased the rapidity of the gains, especially toward the close of the fattening period. However, the lots fed a supplement required about as much concentrates for 100 lbs. gain as the steers fed corn alone on pasture. Mumford concluded that it was clearly advisable to feed a supplement during the last stages of fattening, but that the use of a supplement during the first part of the feeding period for cattle fed corn on bluegrass pasture was of doubtful economic value. Obviously, the higher the price of corn compared with the cost of a supplement per ton, the greater is the advantage from its use. Furthermore, it is more profitable to feed a supplement to well-bred cattle which will sell near the top of the market when well finished, than it is in the case of scrub stock which will not bring the best price, no matter how they are fed.

[15]U. S. Dept. Agr. Bul. 777.

[16]Mo. Bul. 90.

816. Methods of fattening cattle on pasture.—Several different methods are followed by stockmen who fatten cattle on pasture.[17] One group has found it profitable to finish yearlings on bluegrass for late summer and early fall markets. In this system thick, blocky, early-maturing beef calves are wintered so they will gain 150 to 200 lbs. a head. They are then turned on pasture in spring and are fed a liberal allowance of corn or other concentrates in addition thruout the season. Cattle thus handled should weigh 1,100 to 1,200 lbs. about the first of October and usually sell at the top of the market.

Another system quite generally followed is to winter 2-year-old steers on roughage plus a limited amount of concentrates, so that they will go on grass carrying considerable flesh. They usually are fed no grain on pasture until July, after which they are full fed. By the last of September or a little later they are marketed as choice corn-fed cattle. Others feed a more liberal amount of grain in winter and full feed grain from the beginning of the pasture season, so the cattle will reach a good finish in late June or early July, before heavy shipments of grass-fat cattle lower the market prices.

Still another method is to winter cattle on roughage without any grain and graze them on pasture without grain until the pasture begins to fail in the fall. Then the pasture is supplemented by corn and the amount is gradually increased until they are on full feed. Under this system the cattle will reach a high finish by November. Sometimes the cattle are removed to a dry lot about September 1, and fed for 60 to 90 days, thus reaching the market when the supply of fat cattle is usually light and the price consequently good.

In a few sections where the blue grass pastures are especially luxuriant and nutritious, cattle can be brought to a good finish on pasture without any concentrates, even tho they have been fed only roughages the winter previous.

817. Hints on fattening cattle on pasture.—Care should always be taken in changing cattle from dry lot to pasture, especially where they are in good flesh, else they may not continue to gain or may even shrink severely. As young pasture grass is laxative, if silage or roots have been fed during the winter the allowance should be reduced or entirely withdrawn as soon as the cattle are turned to pasture. Dry roughage which is palatable should be fed during the change, for otherwise the cattle may refuse the dry feed, preferring the grass. When the cattle are turned to pasture early in the season and there is no dry grass standing over from the preceding fall, it is wise to leave them on pasture for only a short time the first day and increase the period gradually, else severe scouring may result. If grain has been fed during the winter it should be continued until the cattle are accustomed to grass. Where cattle are nearly finished by the time the pasture season opens they had best be finished in the dry lot, for if turned to pasture they will usually

[17]Largely adapted from Cochel, Breeder's Gazette, 76, 1919, pp. 307-8.

make much poorer gains. Supplying cattle on pasture with salt, shade, and plenty of good water should never be overlooked.

When the corn crop matures before the cattle are finished for market they may be turned into the standing corn, hogs following to get the corn not eaten by the steers. Where this practice is followed the cattle should be accustomed to new corn by being fed gradually increasing amounts of new snapped or ear corn, or corn fodder before being turned into the corn field.

818. Baby beef.—The most intensive method of beef production is the fattening of calves as baby beef. Under this system beef calves are made sufficiently fat for market at 16 to 20 months of age, when weighing about 800 to 1,000 lbs. Profitable baby beef production requires a high degree of experience, judgment, and skill, and it is a mistake for the inexperienced to dip heavily into this art. In calves the natural tendency is towards growth rather than fattening. Therefore to secure the desired finish it is necessary to feed a larger proportion of grain, compared with roughage, than in fattening more mature cattle. Hence this system of beef production is best suited to corn-belt farms, where pasture is relatively expensive but corn is cheaper in price than in other sections of the country. (712) In the production of baby beef, it is essential, first of all, to have blocky, well-bred calves of good beef type and conformation, for scrub or dairy-bred calves will not usually reach the desired maturity and finish at this early age. Calves of the proper sort can not commonly be secured on the large feeder markets, and therefore most cattlemen specializing in baby beef production raise their calves from high-grade beef cows and a good pure-bred bull. The breeding cows are fed and cared for much the same as in the more common type of beef production, which has already been discussed, but they are often fed a little more liberally so as to ensure a good milk flow. The cows must be maintained economically, however, or profits will be eaten up. (788-91) The calves are usually dropped in the latter part of March and in April and May.

In producing baby beef in the corn-belt, the object is to fatten the calves as they grow and to retain their "calf fat." If the calves suffer from lack of feed at any time, it is much more difficult to get them well-finished at the desired weight. During summer the calves run with their dams on pasture, and in addition are commonly fed some concentrates away from the cows at least the latter part of the summer when pastures are short. The concentrates may conveniently be fed inside a creep adjacent to the pasture, which has openings in the fence so that the calves can enter, while the cows are excluded. For feeding the calves on pasture, farm grains should be chiefly fed, as a liberal supply of protein is furnished by their dams' milk and the pasture grasses. A mixture of equal parts shelled corn and whole oats is often used. After they are accustomed to grain, the calves should be fed according to appetite, and they will be consuming 3 to 4 lbs. a head daily by weaning time in the

fall. Since they are used to grain, they will suffer no setback when weaned, but go on making good gains.

When western range calves are bought on the market to be fattened for baby beef, they will not usually carry as much fat as home-raised calves. However, if they are thrifty, well-bred, and of good quality, they can be fattened satisfactorily for baby beef by feeding them good rations, tho they will not be ready for market at as early an age as calves fed liberally at all times.

After the pasture season the calves should be fed palatable, nutritious roughage, such as silage and legume hay. Unless grain is unusually high in price in comparison with other feeds, they should be fed a liberal allowance of corn or other grain, in order to keep them gaining rapidly. If pigs follow the calves, there is no advantage in grinding the corn, and it should be fed as shelled corn or broken ear corn. Calves need a larger proportion of protein than older cattle, and therefore a protein-rich supplement like linseed or cottonseed meal should always be added to balance the ration. The amounts of feed consumed by calves fattened for baby beef and the gains made are shown in a previous chapter. (712) It is there pointed out that calves make much cheaper gains than older cattle, which makes their fattening very economical under corn-belt conditions.

Calves must usually be fed for 8 to 12 months after weaning to reach the necessary finish, while 2-year-old steers can be fattened in 3 to 6 months, depending on the degree of flesh they carry when placed on feed. Heifer calves mature more quickly and may be marketed earlier than steers. It is seldom possible or profitable to get spring calves ready for the baby beef market before July of the following year; more frequently they are not marketed until October, November, or December when approximately 18 to 20 months old. When the baby beeves are to be marketed in summer, quite commonly they are continued in the dry lot until they are sold. If they are turned to pasture, the gains may be much less rapid and more costly than when they are kept on the same rations they were fed in winter.

When corn is high in price compared with other feeds it may be most profitable to feed the calves chiefly on good roughage for the first part of the feeding period and then finish them on a liberal allowance of the grain. In 2 trials at the Kansas Station[18] McCampbell and Winchester fattened calves for baby beef on a ration of only cane silage, alfalfa hay, and a little cottonseed and linseed meal, for the first 4 months and then during the last 3 months full fed them on shelled corn in addition. On this ration an average daily gain of 1.78 lbs. was secured. Other steers fattened similarly, except that they were full fed on corn thruout the entire fattening period, gained 2.08 lbs. a head daily, and sold for 50 cents more per cwt. With corn high in price, it was more profitable to feed no shelled corn the first part of the fattening period. However, with

[18]Kan. Cirs. 86, 92.

corn at usual corn-belt prices, the liberal feeding of grain from the start gave greater net returns.

819. Cost of producing baby beef.—Valuable information on the cost of producing baby beef under corn-belt conditions was secured by Pew and Evvard of the Iowa Station[19] during 3 years thru cooperation with Cassady and Son of the Walnut Ridge Stock Farm in Iowa. On this farm a herd of 75 to 90 head of high-grade Hereford cows was used for the production of calves to be fattened for baby beef. In the fall and winter the cows were kept in vigorous condition on the cheap feeds of an ordinary corn-belt farm, such as meadow-aftermath, stalk fields, alfalfa or mixed hay, and corn silage, no grain being fed in addition. In summer the cows and calves were grazed on bluegrass pasture without additional feed, except that 20 lbs. of silage per head daily was fed one summer when the pasture had been parched by drought. No grain was fed the calves until July or August, when they were started on a mixture of equal parts shelled corn and whole oats. After they were accustomed to grain they were fed according to appetite, and consumed about 3.25 lbs. a head daily up to weaning time.

On this farm the calf crop ranged from 84 to 90 per ct. and the average weight of the calves at weaning time was 413 lbs. The average cost per calf at weaning age under pre-war conditions was $30.40, including the grain eaten by the calves and all the costs of keeping the cows, such as feed, labor, bull service, veterinary charges, mortality risk, taxes, interest, and depreciation. It was found that each year the cost of raising the calves was less than calves of similar quality could have been bought for on the market, the saving averaging $5.08 a head for the 3 years. The cost of raising calves suitable for baby beef in the corn-belt under present conditions would not differ widely from the cost in this investigation. The cost of fattening baby beeves after weaning may be estimated from the data in a previous chapter by computing the probable cost of the gains at current prices for feed and estimating the other expenses, such as labor, interest, building charges, etc. (712)

820. Fattening yearlings.—Less extreme than the feeding of calves for baby beef is finishing steers as yearlings; i.e., before they are 2 years old. Spring calves may be carried thru the first winter on roughage with but a small allowance of concentrates. However, the ration must be such as to keep them growing steadily. The second summer good pasture alone will be sufficient to put them into condition for the feed lot in the fall.

Calves to be fattened as yearlings should be taught to eat grain before being weaned so that there may be no loss of condition at this time. Yearlings can hardly be finished in a 6-months winter feeding period, but require fattening for 8 to 10 months, even if of good beef type. Skinner and Cochel conclude from 3 years' trials at the Indiana Station[20]

[19]Iowa Bul. 181.

[20]Ind. Bul. 142.

that it is ordinarily more profitable to complete the fattening in the feed lot, rather than turn the half-finished cattle out to grass in the spring, for larger and cheaper gains are thus made. (711-2)

821. Fattening cattle 2 years old or older.—Where pasturage is cheap, cattle are usually not marketed until 2 years old or older. They may be carried thru the first winter chiefly on roughage, or even entirely, if fed legume hay and other roughage of good quality. (797) On good pasture they will make good growth the following summer. If they are to be finished on grass early the third summer they will need a moderate allowance of concentrates the second winter. If to be sold in the fall or after finishing in the feed lot, little or no grain will be required provided good quality roughage is fed.

According to Cochel[21] the system of beef production usually most profitable in western Kansas is to raise the calves on pasture the first summer, winter them on kafir, milo, or sorghum silage, alfalfa hay and straw or stover from the sorghums, with perhaps some cottonseed meal in addition, pasture the yearlings the second summer without feeding grain, carry them thru the second winter as before, and market the third summer from grass. With good pasture such cattle should reach a weight of about 1,050 lbs. and be fat enough to sell as fleshy feeders or fair killers. In other sections of the western grazing district a still more extensive system is yet followed, the steers not being sold until 3 years of age. However, the tendency is ever toward hurrying the steer to the block, and while 4- and 5-year-old steers were once common on the range, but few now reach these ages.

822. Cost of fattening cattle.—The cost of fattening cattle will vary widely in different sections of the country and at various times. The chief items of cost are, of course, the initial cost of the feeder cattle and the cost of the feed. Other operating expenses which must be charged against the feeding operations are man and horse labor, building and equipment charges, interest, mortality risk, any veterinary services, insurance, taxes, marketing costs, and incidental expenses.

It is commonly assumed that when cattle are full-fed on corn, the by-products of the fattening operations—the manure secured and the pork produced by the pigs following the steers—will usually pay for all costs other than the initial costs of the cattle and the cost of the feed. Investigations by the United States Department of Agriculture show this to be true unless the cattle are grazed on pasture without grain in addition for a considerable part of the fattening period.[22] In studies at the Illinois Station[23] it was found that 2-year-old steers excreted in feces and urine on the average 87.4 per ct. of the nitrogen and 86.5 per ct. of the phosphorus in their feed. It may be assumed that over 90 per ct. of the potassium is excreted, as well. Thus nearly all the fertilizing con-

[21] Information to the authors.

[22] Wilcox, Jour. Farm. Economics, 3, 1921, pp. 62-72.

[23] Grindley, Mumford, Emmett, and Bull, Ill. Bul. 209.

stituents in the feeds used in fattening cattle may be recovered in the manure, if proper care is taken of this valuable by-product.

The probable cost of fattening cattle on various rations may therefore be estimated approximately from the extensive data in the previous chapters, showing the feed required for 100 lbs. gain under various conditions and with different feeds. It should be borne in mind that most of the trials reviewed were carried on with cattle of good quality, fed first-class feed under expert supervision. Under farm conditions quite commonly slightly more feed will be required for 100 lbs. gain than was needed in these trials, due chiefly to poorer quality of feeds or of animals.

In an extensive survey of fattening beef cattle on corn in Indiana, Illinois, Iowa, Nebraska, and Missouri, including data on 34,934 cattle, the United States Department of Agriculture[24] found that the cattle averaged 786 lbs. when placed on feed, were fed for 174 days on the average, and made average daily gains of 1.63 lbs. and an average total gain of 284 lbs. during the feeding period. For each 100 lbs. gain there were required 680 lbs. grain, chiefly corn, 62 lbs. commercial concentrates, chiefly linseed and cottonseed meal, 391 lbs. hay and other dry roughage, 863 lbs. silage, and 20 days of pasturage.

Wilcox[25] found that in making each 100 lbs. gain there were required 4.5 hours man labor and 3.0 hours horse labor in feeding operations covered by this survey. As by-products to offset the labor and other incidental operating costs there were produced for each 100 lbs. gain 1.3 loads of manure and 27.1 lbs. of pork.

Where the feeding equipment is convenient it may be safely estimated that a man and team can care for and feed 200 cattle, together with the pigs following.[26] This includes not only feeding the grain, but also hauling hay or other roughage to the feed lot from nearby stacks or mows, providing bedding, attending to water, and looking after the wants of steers affected with injuries, lump-jaw, lice, and itch, etc.

[24]Black, U. S. Dept. Agr. Farmers' Bul. 1,218.
[25]Jour. Farm Economics, 3, 1921, pp. 62-72.
[26]Mumford, Beef Production, pp. 33-4.

CHAPTER XXX

GENERAL PROBLEMS IN SHEEP HUSBANDRY

The sheep is the plant scavenger of the farm. Because of its dainty manner of nibbling herbage, we might suppose that its likes were few and dislikes many, yet no domestic animal is capable of living on more kinds of food. Grasses, shrubs, roots, the cereal grains, leaves, bark, and in times of scarcity seaweed, the resinous, pungent leaves of evergreens, fish, and meat, all serve as food for this wonderfully adaptive animal. While horses and cattle eat only about half the plants considered weeds, less than one-tenth of them are refused by sheep. They even prefer some weeds, when yet succulent, to the common grasses. Sheep graze more closely than other stock, and if many are confined to one field every green thing is at length consumed. When closely pastured on cut-over timber lands they derive much nourishment from the leaves, bark, and twigs, destroying the brush nearly as effectively as goats. The feces of the sheep show the finest grinding of any of the farm animals, and as they relish most weed seeds this further fits them as weed destroyers. As sheep graze, their droppings are distributed more uniformly than with other stock. At nightfall they instinctively seek higher, usually poorer, land and thus leave their droppings where most needed. Thru increasing the fertility of the pastures it grazes, this animal has won the title of "The Golden Hoof."

823. The place of sheep on the farm.—On most stock farms in the corn belt and eastward, sheep raising is not the main farming enterprise, but a medium-sized flock, that will profitably fit into the other lines of farming, is often maintained. Because sheep will eat almost any kind of forage, a flock of 25 to 50 breeding ewes can get no small part of their feed from material which would otherwise be wasted. They will clean up the lanes, stubble fields, and fence rows, helping to keep weeds from becoming a pest. Tho the cost of maintaining them may be lowered thru utilizing such waste products, one must not expect profitable production from such feed alone. On rough or hilly land that cannot be economically tilled sheep may be the main live stock of the farm.

Sheep have many other advantages for the farmer. Only a relatively small investment is necessary to start in sheep husbandry, since the foundation animals cost but little and the flock increases rapidly. Sheep require neither expensive barns nor implements and only a minimum of care and attention during the busy summer season. In wool and in the flesh of her offspring, the ewe gives double returns each year. With fair prices, the wool pays for her maintenance, leaving as profit all in-

come from the lamb or lambs, after deducting the small cost of the additional feed and care they require. Returns come quickly, for lambs may be marketed 8 or 9 months after the ewes are bred. While surpassed by the pig in economy of meat production, the lamb requires less feed per pound of product than the steer.

For success with sheep, it is even more essential than with other classes of stock that they be given careful attention, especially at certain seasons, such as breeding, lambing, and weaning. However, the principles of feeding and management are relatively simple and easily understood. In some districts the dog nuisance is a serious obstacle in raising sheep, but fortunately several states have enacted effective dog laws which protect the sheepman. Also, the flock may be safeguarded by means of fences, corrals, and trained dogs.

824. Types of sheep.—The original fine-wool, or Merino, sheep were developed primarily for the production of wool and have bodies which, like that of the dairy cow, are inclined to be angular in form. The story of the Spanish Merino in its home country forms one of the most interesting chapters in the history of live stock.[1] In their pilgrimage from South to Central Spain each spring and their return in the fall the great flocks made annual journeys of over a thousand miles. Only the strongest and most rugged survived the long, fatiguing marches. The ability to exist in enormous flocks, to range over a vast territory, and to subsist upon scant food are the leading of the many remarkable qualities wrought by stern Fate into the very constitution of the Merino sheep.

Almost opposite in several characteristics are the mutton sheep, comprising the middle- and long-wooled breeds, which were developed in Great Britain primarily for the production of meat, with wool secondary. In shape of body these breeds resemble the beef breeds of cattle, being blocky and compact. In the districts in which these breeds were developed they were reared in small flocks confined to limited pasture, the best specimens being saved and nurtured each year with intelligent attention to all their wants. They have been sheltered from storms and liberally fed with rich roughage and grain in the sheepfold whenever the fields were scant of herbage or the weather severe. In general the life of the English mutton sheep has been one of quiet contentment and plenty. In this country we cannot hope to attain the wonderful success reached by British flockmasters unless we closely follow or improve upon their methods.

During more recent years the Delaine-Merinos and the Rambouillets have been developed from the original Spanish Merinos, with the object of securing a fine-wool sheep that would furnish more mutton. These are of dual-purpose type, between the two extremes in form of body.

825. Size of the flock.—The sheep is distinctly gregarious. The improved American Merino still shows the result of inheritance in its

[1] Low, Domestic Animals of the British Islands, Vol. II.

ability to exist in great flocks and thrive under the most ordinary conditions of care and keep. In the grazing districts of the West thousands of sheep carrying more or less Merino blood are held in single bands where the range furnishes sufficient feed, and tens of thousands may be successfully fed together, as is still done with range sheep which are brought to feeding points in the western states and in the Mississippi valley.

In the humid regions, however, 200 sheep of the mutton breeds are as many as can usually be successfully managed in one flock, for when the farm is heavily stocked with sheep, the troubles from stomach worms and other parasites are much greater. The beginner had best begin with a flock of 25, increasing the number as experience grows.

826. Breed tests.—The experiments which have been carried on to compare the various breeds of sheep have not yet been extensive enough to warrant definite conclusions concerning any differences in economy of production. Two trials by Wilson and Curtiss at the Iowa Station[2] furnish the most complete data yet available. Wethers of various breeds were fed the same rations for periods of 90 and 105 days, respectively. Nine breeds were compared in these tests—Merinos, Dorsets, Oxfords, Shropshires, Southdowns, and Suffolks among the medium-wooled breeds; and Cotswolds, Leicesters, and Lincolns among the long-wooled breeds. The "Merinos" (which were Delaine-Merinos in the first trial and Rambouillets in the second one) made the smallest daily gains and required the largest amount of feed per 100 lbs. gain, due to the fact that they are slow-maturing and are not primarily mutton sheep. The long-wools made somewhat the largest gains and yielded the heaviest fleeces. Considering the relatively small numbers of each breed included in the trials, there were no significant differences among the mutton breeds in the amounts of feed required for 100 lbs. gain.

827. Cross breeding for the western ranges.—In earlier years the sheep on the western ranges were of Merino blood, for wool was the product sought. When the demand for lamb and mutton increased, rams of the mutton breeds were used on the range ewes to improve the mutton qualities of the offspring. It has been found, however, that the introduction of mutton blood can not go beyond a certain degree in the range flocks of breeding ewes, or they will lose both their hardiness and their Merino herding instinct, and will scatter on the range so that many are lost or fall prey to wild animals. A rather troublesome system of crossbreeding must accordingly be followed in range flocks, in order to produce lambs of good mutton conformation and yet retain sufficient Merino blood in the breeding ewes.

To avoid this, the Corriedale breed was developed in New Zealand by crossing Lincoln and to a lesser extent Leicester rams on Merino ewes, mating the hybrids together, and selecting the offspring with the desired qualities. The value of this breed for American range conditions

[2] Iowa Buls. 33, 35.

is being tested by the United States Department of Agriculture and various ranchmen, and also attempts are being made to develop along the same line an American breed, the Columbian, which will fit western conditions.

828. Building up the farm flock.—Often the most economical way for a farmer to establish a flock of sheep is to buy young, thrifty western range ewes of good conformation. These are commonly less infested with internal parasites than native eastern ewes. By the use of a good type pure-bred mutton ram on such ewes, an excellent flock may soon be developed, and the lambs of even the first cross will show pronounced improvement in mutton characteristics. By continued use of pure-bred rams of the same breed, a flock of excellent mutton type and conformation will soon be built up which can scarcely be distinguished from pure-breds.

Faville,[3] at the Wyoming Station, mated 29 fine-wooled western ewes with a good Cotswold ram and another lot with a Southdown ram, and fattened the resulting lambs. The Cotswold grades made slightly larger and more economical gains, but the Southdowns gave a higher percentage of dressed carcass, worth more per pound. Carlyle and Iddings,[4] on fattening a lot of 139 Lincoln-Merino lambs and 161 Shropshire-Merinos at the Idaho Station, found that the latter made slightly larger gains, while the feed consumed per 100 lbs. gain was practically the same for both lots.

If native ewes are purchased locally to start the flock, it is important that they be vigorous, thrifty, free from disease, and of as uniform breeding as possible. In certain sections of the eastern states native Delaine-Merino ewes can be purchased more cheaply than ewes of the mutton breeds. As they are also hardier, they make desirable foundation stock for building up a farm flock by the use of pure-bred mutton rams. In trials at the Pennsylvania Station[5] Tomhave and McDonald found that cross-bred lambs from Delaine-Merino ewes and Shropshire or Southdown rams made considerably more rapid gains than Merino lambs. Furthermore, the return per lamb over cost of feed consumed by the lamb was only $5.95 for the Merino lambs, while it was over $8.00 for the cross-bred lambs.

829. Fattening lambs versus older sheep.—The tender, juicy, high-flavored meat from lambs is in much greater demand than mutton from older sheep, even tho they be well fattened. Hence, fat lambs sell for a much higher price per hundredweight on the market than fat yearlings or older animals. For this reason, and also because lambs make much cheaper gains than older sheep, ordinarily lambs which are not to be retained for the breeding flock are never carried over to the second year. Only when wool is unusually high in price may it be profitable to do otherwise. If lambs raised on farms are not sufficiently fat in

[3] Wyo. Bul. 95. [4] Idaho Bul. 77. [5] Penn. Bul. 163.

A Profit-making Farm Flock at Pasture

On many farms where most of the income is derived from other sources, a flock of sheep would bring additional profits, since they consume much food which would otherwise be wasted.

The Sheep Has Won the Title of "The Golden Hoof"

Thru increasing the fertility of the pastures it grazes, this animal has won the title of "The Golden Hoof." As sheep graze, their droppings are distributed more uniformly than with other stock.

SHEEP KEEP LANES AND FENCE CORNERS CLEAN

Most weeds are eaten readily by sheep. They therefore help the farmer keep his lanes and fence corners clean.

LAMBS BRING QUICK RETURNS

If lambs are properly fed concentrates in addition to their dams' milk, they will be ready for market before weaning, bringing a high price and quick returns.

late summer or early fall to meet the reasonable demands of the market, it shows a lack of feed and care, or that parasites have destroyed profits.

The relative cost of gains by lambs and older sheep is well shown in a trial by Shaw at the Montana Station.[6] Western range lambs, yearling wethers, and 2-year-old wethers were fed for 88 days, with the results shown in the table:

Fattening range sheep of different ages

Age when fed	Average ration		Av. wt. at beginning	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Barley Lbs.	Clover hay Lbs.	Lbs.	Lbs.	Lbs.	Barley Lbs.	Clover hay Lbs.
Lambs	0.7	2.1	63	0.27	23.7	253	763
One-year-old wethers	0.7	3.8	95	0.27	23.5	256	1,413
Two-year-old wethers	0.7	4.1	116	0.28	24.3	248	1,469
Aged ewes	0.7	2.3	92	0.18	15.6	387	1,320

It will be observed that all lots, except the aged ewes, made practically the same daily and total gains. All were fed the same amount of grain, but the lambs ate about half as much hay as the yearlings or 2-year-olds. Hence the gains of the lambs were much more economical. In other trials at the same Station, lambs made not only more economical but also more rapid gains than yearling wethers. In a trial by Paterson and Winchester at the Kansas Station[7] western lambs gained 0.39 lb. a head daily, while yearlings gained only 0.29 lb. The feed cost of 100 lbs. gain was 56 per ct. more for the yearlings than for the lambs.

Most stockmen who fatten western feeder sheep for the market prefer lambs to older sheep for the reasons given previously. Tho lambs cost more per cwt. as feeders than older animals, they sell for so much more when fat that there is usually a greater margin between cost and selling price per cwt. than in the case of the older animals, and hence a greater profit in fattening them. Some men make a practice of purchasing old ewes, which can often be obtained at low prices. Such animals require expert care and good feed. In the West they are often fed largely on beet pulp, as this is especially suited to those with "broken mouths," or poor and missing teeth.

Owing to their tendency to grow, lambs require a longer period to fatten than do mature wethers. Since they are making not only fat but also lean meat, the ration should be somewhat narrower, that is, contain more protein, than is needed for fattening mature sheep. However, a ration which is too rich in protein will unduly stimulate growth, and not fatten them properly.

830. Shelter for sheep.—Above every other animal on the farm, sheep should be kept dry as to both coat and feet. Inattention to either of these essentials will result disastrously. With dry winter quarters sheep will stand a great degree of cold without injury. Their shelter should not be warm, compared with that of other farm animals, for sheep

[6] Mont. Buls. 35, 47, and 59. [7] Information to the authors.

sweat badly in winter when confined in quarters sufficiently warm for dairy cows. One thickness of matched boards will make the barn or shed where sheep are confined sufficiently warm in the northern states, except for winter lambs. Ample ventilation is of great importance, but drafts must be avoided. On the western plains, it is even more necessary to protect sheep from cold winds than from rain. Sunshine, good drainage, and conveniences for feeding are the other requisites of a good sheep barn. When succulent feeds, such as wet beet pulp or silage, are fed, the quarters must be especially well drained and the barn or shed well bedded. Stone basements are unsatisfactory for sheep on account of dampness, and if used good ventilation is especially necessary. Damp walls are a sure indication of lack of ventilation and impending trouble.

In late spring and early summer the flock should be sheltered, if possible, from cold rains, for exposure is dangerous, especially for young lambs. In summer, if there is no natural shade in the pastures, the flock should have access to a darkened but well ventilated shed. A fringed curtain thru which the sheep force their entrance will keep back the flies from this retreat. (881)

831. Winter quarters for fattening sheep.—The kind of shelter it is advisable to provide for fattening lambs and sheep in winter will of course depend on the climate in the given district. During each of 5 winters Skinner and King fed one lot of western lambs at the Indiana station[8] in a well-ventilated barn and another lot in an open shed with a yard for exercise adjoining. In all except one trial the lambs in the shed made a trifle more rapid gains than those in the barn and in each trial returned slightly more profit. On the average, the feed cost of 100 lbs. gain was 12 cts. less, the selling price per 100 lbs. 15 cts. greater, and the net return per lamb 17 cts. more for those in the open shed.

To find whether there was any advantage in providing more shelter than an open shed in a more northern climate, Morrison and Kleinheinz fed a lot of 40 western lambs during each of 3 winters at the Wisconsin Station[9] in an open shed, partly boarded up to provide additional protection from the wind and snow, and another lot in a well-ventilated barn. Each lot was turned out for exercise for a short time daily, except in stormy weather. On the average, the lambs in the barn gained 0.395 lb. a head daily and those in the shed 0.386 lb. In each trial there was no difference in the finish or the selling price of the lambs, but the average cost of feed for 100 lbs. gain was 4.6 per ct. higher for the lambs in the shed, and therefore the net return over cost of feed was slightly less than for lambs in the barn. In a trial by Shaw at the Minnesota Station[10] a lot of lambs fed in a yard with no shelter, but protected from the wind by a low building at one side, gained 12 per ct. less and required about one-fourth more feed for 100 lbs. gain than

[8] Ind. Buls. 168, 179, 184, 192 and 202.

[9] Wis. Bul. 323, p. 13; unpublished data.

[10] Minn. Bul. 44.

others which had the shelter of an open shed. Lambs confined in a barn made slightly smaller and less economical gains than those in the open shed.

In districts with a mild winter climate, all that is needed is protection from winter rains and driving snows. Where the winters are relatively dry, most feeders believe that there is no advantage in providing even an open shed, but they feed fattening lambs in a yard with no shelter except a board windbreak. To study this matter Gramlich fed 2 lots of lambs at the Nebraska Station[11] during a winter when there were 2 hard rains and considerable snow and cold weather. Lambs fed in a yard with merely a windbreak made just as rapid gains as where an open shed was provided and returned a slightly larger profit. In 3 trials at the Eastern Oregon Branch Station[12] by Withycombe and Potter, lambs having access to an open shed made slightly larger gains than others which were fed in a yard with no shelter, and required 3.5 per ct. less grain and 3.2 per ct. less hay for 100 lbs. gain. The conclusion reached was that while the shed paid fair returns, it afforded no profit over interest and depreciation. On the other hand, in a trial by Mumford, Trowbridge, and Hackedorn at the Missouri Station[13] yearling wethers fed in a yard made smaller gains and required over 19 per ct. more feed than others which had access to a barn. From these trials we may conclude that for fattening sheep or lambs which are heavily fed and warmly coated there is no advantage in providing more shelter than an open shed except in the extreme northern states. This should open to the south or east to afford shelter from the prevailing winds and should be kept well bedded. In the arid regions, protection from driving winds and sandstorms is all that is essential.

832. Exercise.—For the breeding flock abundant exercise thruout the year is essential. (881) However, for fattening lambs or sheep only limited exercise is preferable. This is shown in trials by Humphrey and Kleinheinz during 3 years at the Wisconsin Station[14] in which one lot of wether lambs was kept in a dry, airy, well-lighted pen in the barn during fattening, while another lot was turned out daily for exercise when the weather permitted. The lambs turned out for exercise made slightly smaller gains and required over 16 per ct. more feed for 100 lbs. gain than those more closely confined.

833. Grinding grain.—Of all farm animals the sheep is best able to do its own grinding, and with few exceptions whole grains only should be furnished. (423) The common saying of feeders, "a sheep which cannot grind its own grain is not worth feeding," is a truthful one. There is generally no advantage in grinding or crushing corn, oats, ordinary barley, emmer, or grain sorghums for sheep. It is well to grind such hard seeds as hulless barley, millet, and screenings containing small weed seeds. Usually whole wheat is satisfactory, but some-

[11]Nebr. Bul. 173.
[12]Ore. Bul. 175.
[13]Mo. Bul. 115.
[14]Wis. Rpts. 1904, 1905.

times considerable passes thru the animals unmasticated. Where grain is prepared for sheep, it should be ground coarsely or crushed, instead of being ground to a fine meal, which is not so palatable to sheep.

834. Cutting or grinding hay.—Whether to cut or grind alfalfa or other hay for lambs or sheep will depend on the price of the hay and the cost of such preparation. From 4 trials in which he tested the value of cutting and grinding alfalfa hay for fattening lambs, Morton of the Colorado Station[15] concludes that grinding ordinary alfalfa hay to a meal may increase its value 15 to 25 per ct., because the coarser parts of the hay will be consumed and the sheep saved some energy in masticating the hay. With hay of choice quality there is little saving thru grinding or cutting. (**424**) In a trial at the Caldwell, Idaho, Substation[16] by Hickman, Rinehart, and Johnson, lambs fed good-quality uncut alfalfa hay made more rapid gains than other lots fed either cut alfalfa hay or alfalfa meal. The cut hay was worth no more per ton than the uncut hay, and the alfalfa meal was not worth enough more to pay for the grinding. In sections where there are rains or snows during the feeding period, if hay which is in stacks is to be cut it should be cut when dry and stored where it is protected from the weather, or it will mold.

835. Self-feeders.—In the days when most of the western lambs and sheep were fattened for market by large operators (**850**), it was a common practice to feed the grain in self-feeders. This system is most successful when a bulky concentrate, like chaffy wheat screenings, is fed for the first few weeks, or when the grain is mixed with finely cut or ground hay, to lighten the mixture and prevent the lambs eating so much heavy grain as to go off feed. (**900**) The more concentrated the grain, the greater is the danger in self-feeding it. Where large numbers of lambs are fed, self-feeders save considerable labor, but trials at several stations[17] show that lambs which are self-fed require more feed for 100 lbs. gain, and furthermore are more apt to go off feed and even die from digestive trouble than when hand-fed by careful men. While self-feeding various feeds by the free choice system gives excellent results with swine, if suitable feeds are used, this system is not suited to fattening lambs. In a trial at the Kansas Station[18] by Paterson, lambs self-fed shelled corn and linseed meal free choice, with alfalfa hay and sorghum silage in addition, made slightly more rapid gains than others hand-fed the same feeds, but at a considerably greater cost for feed.

Certain extensive feeders in Nebraska start lambs on feed by giving them free access to feed bunks or self-feeders filled with pea-size linseed meal, with prairie hay in addition. Contrary to what we might

[15]Colo. Buls. 151, 187.

[16]Idaho Cir. 19.

[17]F. B. Mumford, Mich. Buls. 113, 128; Mo. Bul. 115; Shaw, Minn. Bul. 44; Gramlich, Nebr. Buls. 170, 173.

[18]Kan. Cir. 88.

expect, the lambs do not commonly founder on this heavy, rich meal, tho they often consume 2 to 2.5 lbs. per head the first day. The second day a little corn is mixed with the linseed meal, and each succeeding day the proportion of corn is increased until at the end of about 2 weeks the mixture consists of 4 parts of corn to 1 part of linseed meal. Rapid gains are produced under this system, but Gramlich found it less economical and profitable than hand-feeding in trials at the Nebraska Station.[19]

836. Feed racks.—In fattening sheep in open lots in the West the hay is often fed on the ground outside the pens, being pushed up against the fence so the sheep can get it. From trials during 2 years Morton[20] reports that under Colorado conditions, with lambs fattened in the open, self-feed hay racks accommodating 4 lambs per foot, 2 on a side, saved sufficient hay, compared with feeding it on the ground, to pay their cost in 3 seasons. Hay racks should be so built that chaff and seeds will not fall upon the necks of the sheep, since such material will work down into the wool, injuring its quality.

Grain and roughage should be fed separately to sheep. If sheep are fed in close quarters, the hay should be supplied daily, since they dislike provender that has been "blown on," as shepherds say. In feeding sheep in open lots, as is done thruout the West, racks sufficiently large to hold roughage for several days are often used. Grain troughs should have a wide, flat bottom, forcing the sheep to consume the grain slowly. Fifteen inches of linear trough space should be provided for each animal.

837. Water.—Opinions as to the amount of water necessary for sheep vary more than with any other domestic animal. In countries with heavy dews and ample succulent feed in summer, and where roots are largely used in winter, water may possibly be denied sheep, but ordinarily it is a necessity, and fresh water should be supplied daily. Because of the danger of infestation with internal parasites, drinking from stagnant pools must be avoided. On the arid ranges of the Southwest, when grazing on certain succulent plants, like singed cacti, sheep sometimes go 60 days without water.

A sheep needs from 1 to 6 quarts of water daily, according to feed, temperature and weather. Ewes suckling lambs, and sheep that are being fattened require more water than those being simply carried thru the winter. In trials at the Michigan Station[21] fattening lambs fed grain and clover hay drank 2.8 lbs. of water a head daily, while others fed roots in addition drank only 1.9 lbs. One lot, fed all the sugar beets they would eat, with clover hay, drank only 0.3 lb. a head daily, for they secured nearly all the water they needed in the watery roots. (103) Lambs fed in an open yard required less water than those in confinement, due probably to the lower temperature outside. Supplying lambs fat-

[19]Nebr. Buls. 170, 173.

[20]Colo. Bul. 187.

[21]Mich. Buls. 113, 128, 136.

tening on alfalfa hay and grain with warm instead of cold water made no difference either in the quantity of water drunk or in the rate and economy of the gains produced.

Gray and Ridgeway of the Alabama Station[22] found that in late summer ewes in confinement drank 2.5 lbs. of water each while living on green sorghum forage, and 6.1 lbs. when on cottonseed meal and hulls.

838. Salt; other mineral matter.—Sheep require salt, and it should be available at all times, for an irregular supply induces overeating of the salt, which causes scours. Rather than limiting the supply of salt or mixing it with their feed, it is best to let sheep eat as much as they wish. In an experiment in France[23] sheep fed 0.5 ounce of salt daily with their feed gained materially faster than those fed no salt, and also somewhat more rapidly than others fed 0.75 ounce daily. The fleeces of the salt-fed sheep were of better quality and heavier than those of the sheep fed no salt.

In winter salt may be given in a trough used only for this purpose. In summer salt may be sometimes rendered doubly useful by scattering it on sprouts growing about stumps, on brush patches, or over noxious weeds. To get the salt sheep will eat down such vegetation. Some western sheep raisers never salt their sheep but allow them to eat alkali, which is safe when it contains 80 per ct. salt.[24] It is believed that salted sheep are less liable to become locoed. (**400**)

When fed well-balanced rations containing plenty of protein-rich feeds and especially good legume hay, sheep will ordinarily receive ample calcium (lime) and phosphorus, which are the other mineral nutrients most apt to be lacking in the rations of farm stock. (**95-9**) The richness of legume hay in calcium is one of the reasons why it is so important a feed for breeding ewes. (**884**) Should it be necessary to feed breeding ewes roughages low in calcium, especially straw, calcium should be furnished in the form of ground limestone, chalk, bone meal, or rock phosphate, or weak lambs and even abortion may result. (**98**)

If trouble is experienced from goitre, or "big-neck," in lambs, this may be prevented by administering iodine, as has been pointed out in an earlier chapter. The doses for ewes are the same as those for sows, given in a later chapter. (**917**)

839. Weight and gains of fattened wethers.—By far the most comprehensive data on the weights and gains of fattened wethers of different ages and from various breeds are furnished by the records of the animals winning prizes at the Smithfield Club Show, London, England. In the following table are presented these data for the years 1895 to 1912, inclusive.[25] As given in these records, the daily gain includes the weight of the animal at birth.

[22]Ala. Bul. 148.

[23]Abs. in Agr. Jour. and Min. Rec., 5, 1902, p. 361.

[24]Wilcox and Smith, Farmer's Cyclopedia of Live Stock, p. 590.

[25]Lond. Live Stock Jour., Vols. 42-76.

Weight of prize-winning wethers at Smithfield

Breed	Wether lambs				Yearling wethers			
	Number	Av. age	Av. wt.	Av. daily gain	Number	Av. age	Av. wt.	Av. daily gain
Middle-wool		Days	Lbs.	Lbs.		Days	Lbs.	Lbs.
Cheviot	35	238	141	0.59	53	592	224	0.37
Dorset	49	331	200	0.60	23	679	261	0.38
Hampshire	94	309	208	0.67	78	661	282	0.42
Mountain	36	232	132	0.56	60	591	197	0.33
Oxford	56	298	196	0.66	53	649	285	0.44
Shropshire	57	266	159	0.58	58	636	253	0.39
Southdown	99	286	150	0.52	105	637	202	0.31
Suffolk	76	287	201	0.70	56	648	291	0.44
Long-wool								
Cotswold	25	276	188	0.68	15	624	292	0.46
Devon	42	276	188	0.68	28	625	268	0.42
Kent	73	250	160	0.64	65	606	267	0.44
Leicester	54	247	157	0.64	59	607	273	0.45
Lincoln	48	290	209	0.72	55	639	334	0.52

The greater economy of the gains made by lambs is shown by the fact that the lambs made daily gains ranging from 0.52 lb. to 0.72 lb., while those of the yearlings were considerably lower, ranging from 0.31 to 0.52 lb. per head daily.

840. Slaughter tests; dressing percentage.—The records of the slaughter competitions at the Smithfield Club Show[26] also furnish the most extensive data available on the dressing percentage, and weight of internal fat, pluck (heart, liver, and lungs), and skin for wethers of the different breeds. In the following table are averaged results of these "block" tests for 20 years, 1895-1914 inclusive.

Smithfield slaughter tests

Breed and age	Av. live wt. at slaughter	Av. wt. of dressed carcass	Av. per ct. of dressed carcass	Av. wt. of fat	Av. wt. of pluck	Av. wt. of skin	No. of animals
	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	
Blackfaced, lambs	116	71	61	6.6	3.7	14.6	7
Blackfaced, 1–2 years	171	110	64	9.0	4.4	18.6	16
Cheviot, lambs	113	67	59	5.8	3.6	12.6	54
Cheviot, 1–2 years	147	94	64	6.9	4.4	14.3	68
Hampshire, lambs	163	102	63	5.2	5.1	15.0	54
Hampshire, 1–2 years	209	135	65	6.8	6.0	15.8	30
Kent, lambs	141	85	60	5.2	5.0	19.4	5
Kent, 1–2 years	242	155	64	5.5	6.0	27.0	2
Shropshire, 1–2 years	259	175	68	6.2	7.0	25.2	4
Southdown, lambs	123	76	62	4.3	3.9	10.8	54
Southdown, 1–2 years	142	92	65	6.2	4.1	12.0	45
Suffolk, lambs	152	95	62	7.0	5.0	13.6	104
Suffolk, 1–2 years	188	121	64	10.6	5.7	14.3	43
Welsh, 1–2 years	121	74	61	8.8	3.4	11.0	14
Cross-bred, lambs	129	79	61	5.9	4.2	13.2	106
Cross-bred, 1–2 years	161	102	63	8.3	5.0	14.8	101

[26]Lond. Live Stock Jour., Vols. 42-80.

It will be noted that the yearlings yielded a slightly higher percentage of dressed carcass than the lambs. These wethers were thoroly finished, and thus their dressing percentage is higher than with sheep as usually fattened for the market.

841. Yield of dressed carcasses; shrinkage.—The slaughter tests at the various stations in this country show that lambs and yearlings dress from 48 to 57 per ct., depending on how completely they are fattened.

Shaw[27] states that fattened lambs weighing over 100 lbs., when 4 days in transit, will shrink 7 to 8 lbs. per head; 1-year-old wethers weighing about 120 lbs., approximately 10 lbs.; and aged wethers and ewes about 12 lbs. per head.

During 4 winters Linfield shipped lambs and 2-year-old wethers fattened at the Montana Station[27a] to Chicago, a distance of about 1,440 miles. The lambs, which averaged 87.5 lbs. in weight when shipped, shrank 7.6 per ct. on the average, the range being 4.6 to 8.7 per ct. The 2-year-old wethers shrank somewhat less, averaging 6.8 per ct. with a range of 5.1 to 8.6 per ct. The older sheep yielded 2.2 per ct. more dressed carcass. On shipping lambs fattened in 4 trials on corn and either clover hay, alfalfa hay, corn stover, soybean straw, or timothy hay, with and without the addition of a nitrogenous supplement, Carmichael and Hammond of the Ohio Station[28] found no variation in shrinkage attributable to the ration. Lambs shipped 135 to 149 miles shrank 1.3 to 6.8 per ct.

When sheep are marketed off pasture, especially rape, excessive shrinkage from scouring may be prevented by giving dry feed for a day or more prior to shipping. The grain ration should be decreased for the same reason. Oats is an excellent feed for sheep in transit.

842. Wool production.—A general discussion of the factors concerned in the production of wool has already been given in Chapter VI. (**151-2**) It has there been pointed out that lambs which are so fed that they make larger growth yield more wool. This is shown in a trial by Wilson and Kuhlman at the South Dakota Station[29] in which adding linseed meal to a ration of corn, oats and prairie hay (an unbalanced ration, low in protein) increased the gain 37 per ct., reduced the feed required for 100 lbs. gain, and increased the yield of wool 9 per ct. On the still better ration of corn, oats, and alfalfa hay, the lambs gained 72 per ct. more, required only three-fourths as much feed for 100 lbs. gain, and produced 60 per ct. more wool than those fed the unbalanced ration. This well shows the importance, both for growth and for wool production, of feeding lambs balanced rations. (**844, 857**)

Formerly it was the common practice in many districts to wash sheep before shearing, by driving them repeatedly thru a stream or by holding them in the water and squeezing the dirt out by hand. Such washing is of no benefit to the manufacturer, for the wool must in any event be scoured to remove the wool fat, before it can be used, and the wash-

[27]Management and Feeding of Sheep, p. 365.
[27a]Mont. Buls. 47, 59.
[28]Ohio Buls. 187, 245.
[29]Information to the authors.

ing does not lower the cost of scouring nor improve the quality of the wool. (151) The price paid by a manufacturer for any lot of wool is based merely on the estimated yield and quality of scoured wool.

As the practice of washing sheep still persists in some localities, Hammond studied the matter in a trial extending over 2 years at the Ohio Station.[30] He found that a sufficient premium is not usually paid for washed wool to offset the reduction in gross pounds of wool yielded and the labor of washing, a difficult and unpleasant task.

In the corn belt and eastward sheep are usually shorn between the middle of April and the middle of May, when the weather has become settled and there have been a few days too warm for the comfort of unshorn sheep. The yolk has then risen into the wool in sufficient quantity to make it "full of life" and to make shearing easy. If shearing is delayed too long, the wool becomes dead and lifeless, the sheep suffer from the heat and are troubled more with maggots about the breech, due to the wool becoming foul.[31] Hammond found that sheep shorn each year on April 12 yielded 0.16 lb. more scoured wool than those shorn on June 1, but 0.71 lb. less wool in the grease.

To prevent injury to the wool, feeding racks should be so constructed that seeds and chaff will not lodge on the neck and shoulders of the sheep, and the feed lot or barn must be kept well bedded, so that the wool will not become soiled.

Fattening lambs and sheep are often shorn either before being placed on feed or during the early part of the fattening period, for the purpose of stimulating their appetites and making them more comfortable. This practice is followed especially when the animals are on feed late in the spring and the weather becomes warm, or when lambs are purchased early in the fall to be turned into corn fields and stubble fields.

Various experiments conducted at the Indiana, Michigan, Nebraska and Wisconsin Stations[32] show in general that lambs or other sheep which are clipped will not usually make materially larger or more economical gains than if unshorn, unless the weather is so warm that they would be uncomfortably warm otherwise. They should never be shorn during cold weather, unless good shelter is available. Before shearing, one should find out the probable difference in price there will be between fat clipped and unclipped sheep, and also know about how much wool he will secure by clipping and the price it will bring. Often the margin between clipped and unclipped sheep is so great that clipping is unprofitable, even tho it may cause the animals to make a trifle more economical gains. On the other hand, a person who is posted on market conditions can not infrequently make a good profit by clipping the sheep before they are sold. If clipped, more sheep can be shipped in a car.

[30]Ohio Bul. 294. [31]Coffey, Productive Sheep Husbandry, pp. 322-3.

[32]Skinner, King, and Starr, Indiana Buls. 168, 202, 221; F. B. Mumford, Mich. Bul. 128; Gramlich, Nebr. Buls. 167, 170 and information to the authors; Craig, Wis. Rpt. 1904.

CHAPTER XXXI

FEEDS FOR SHEEP

I. Concentrates for Sheep

In the following articles, which discuss the value of various feeding stuffs for sheep, especially for fattening animals, it will be noted that nearly all the trials reviewed were with lambs. This is due to the facts, already pointed out, that lambs make better use of their feed than older animals and that their flesh is in greater demand. (829) In all trials where the weight of the lambs and duration of the fattening period are not stated, it may be assumed that western lambs weighing 55 to 65 lbs. were used, and that the feeding period covered from 12 to 15 weeks.

843. Indian corn.—Corn, the best single grain for fattening sheep, is the cereal most commonly used over the United States as far west as Colorado, beyond which wheat and barley are more generally fed. (201-7) Legume hay, rich in protein, admirably supplements this carbonaceous grain. Hence, the combination of corn and legume hay has become a standard ration for fattening sheep over a large part of our country. In this chapter, so far as possible, other rations are compared with this successful combination. To show the possibilities of this ration, below are averaged the results from 8 stations with 26 lots, including 527 lambs, which were fed an unlimited allowance of shelled corn and either clover or alfalfa hay, for periods averaging 90 days. The results are also given from 4 stations at which 17 lots, including 1,180 lambs, were fed a limited allowance of shelled corn (from 0.7 to 1.1 lbs. per head daily), with the same roughages, in trials averaging 92 days.

Corn and legume hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Feed for 100 lbs. gain Hay Lbs.
Corn allowance unlimited				
Shelled corn, 1.3 lbs.				
Clover or alfalfa hay, 1.4 lbs.....	67	0.32	400	436
Corn allowance limited				
Shelled corn, 0.9 lb.				
Clover or alfalfa hay, 2.1 lbs.....	60	0.32	288	655

The lambs given a full feed of corn consumed an average ration of 1.3 lbs. shelled corn and 1.4 lbs. clover or alfalfa hay and gained 0.32 lb. per head daily, requiring 400 lbs. shelled corn and 436 lbs. hay per 100 lbs. gain. Usually lambs fed a limited allowance of grain will gain less rapidly than those fed all the grain they will eat. However,

in these trials, the lambs fed the limited allowance of corn with alfalfa or clover hay gained as fast as in the trials where the lambs were fed an unlimited allowance of corn. This was probably due to the superior quality of hay fed. These lambs required 655 lbs. of hay and only 288 lbs. of corn for 100 lbs. gain. From the averages given in this table, the feeder may readily calculate the cost and possible profits of fattening lambs on such a ration, under reasonably favorable conditions and when the fattening period is not too extended. (**901**)

It has been pointed out in an earlier chapter that yellow corn contains considerable of the fat-soluble vitamine, while white corn has but little. (**104**) However, we would not expect this to give yellow corn any superiority over white corn for sheep feeding in general, for sheep ordinarily receive roughage which is rich in fat-soluble vitamine. In a 40-day trial at the Kansas Station[1] by Paterson and Winchester with yearling wethers, yellow corn proved superior to white corn when fed with alfalfa hay, sweet sorghum silage, and enough cottonseed meal to balance the ration. Further data are needed before definite conclusions are drawn concerning the relative value of the two kinds of corn for sheep feeding.

844. Corn requires supplement.—Owing to its carbonaceous character, corn should be supplemented with some variety of legume hay, or if this is not available then with some protein-rich concentrate, even when fed to fattening sheep or lambs. (**201**) The following table summarizes the results of 7 trials, averaging 81 days, in each of which corn was fed with clover or alfalfa hay to one lot of 59-lb. lambs and with timothy or prairie hay to another lot:

Legume hay as a supplement to corn

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain	
		Concentrates Lbs.	Hay Lbs.
*Unbalanced ration, 164 lambs**			
Corn, 0.9 lb. Carbonaceous hay, 1.0 lb.....	0.19	497	547
*Balanced ration, 172 lambs**			
Corn, 1.1 lbs. Legume hay, 1.5 lbs.....	0.32	340	475

*Average of 1 trial by Burnett (Nebr. Bul. 66), 1 by Emery (Wyo. Bul. 51), 1 by Faville (Wyo. Bul. 85), 1 by Morton (Wyo. Bul. 73), and 3 by Skinner and King (Ind. Bul. 162).

While the lambs fed corn with timothy or prairie hay gained only 0.19 lb. per head daily, those fed corn with clover or alfalfa hay gained 0.32 lb. The lambs on the unbalanced ration required 46 per ct. more grain and 15 per ct. more hay than those on legume hay.

When carbonaceous hay must be fed to fattening lambs, it is necessary that the ration be balanced by the use of some protein-rich concentrate in order to secure economical gains. This is shown clearly in the following table, giving the average results of 4 trials in which this question has been studied:

[1]Information to the authors.

Cottonseed or linseed meal as supplement to corn

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain: Concentrates Lbs.	Feed for 100 lbs. gain: Hay Lbs.
*Unbalanced ration, 90 lambs**				
Corn, 1.2 lbs. Timothy hay, 1.0 lb.....	64	0.23	520	448
*Balanced ration, 90 lambs**				
Corn, 1.2 lbs. Supplement, 0.2 lb. Timothy hay, 1.0 lb.	64	0.30	463	334

*Average of 1 trial by Carmichael and Hammond (Ohio Bul. 245), 1 by Hays (Minn. Bul. 31), and 2 by Skinner and King (Ind. Bul. 162).

Supplementing the carbonaceous ration of corn and timothy hay with 0.2 lb. of protein-rich cottonseed or linseed meal per head daily, increased the gains and lowered the amount of feed required for 100 lbs. gain. Lambs will go off feed more readily when corn is fed without being properly supplemented by some protein-rich feed. On the other hand, in these trials the lambs fed corn and legume hay or corn, carbonaceous hay, and a nitrogenous supplement had good appetites at all times.

845. Corn alone and in combination.—Altho corn and legume hay alone have given excellent results in numerous experiments and in extensive commercial feeding, many maintain that the animals have better appetites and are less subject to digestive disorders when a variety of grains is used, especially toward the close of the fattening period, or when lambs are being forced on heavy grain allowances. In starting sheep on feed it is, without any question, advisable to mix a more bulky concentrate, such as oats or wheat bran, with the corn, to prevent digestive trouble. Whether there is any benefit in adding other feeds to corn for variety when the lambs are on full feed seems to be doubtful, for in trials reviewed later (**851**), just as good results were secured with corn as the sole concentrate, when fed with clover hay and corn silage, as with a combination of corn and oats. Much of the trouble experienced in feeding corn as the sole concentrate is due to its improper use with carbonaceous roughage and without any nitrogenous supplement.

Lambs grazing on bluegrass pasture were fed corn meal alone, both before and after weaning, in comparison with others fed either corn meal and oats or corn meal and peas, in trials by Craig at the Wisconsin Station.[2] Fully as large and economical gains were secured on corn alone as on the mixtures. With these lambs the protein necessary to balance their ration was furnished by their dams' milk and the pasture grass.

846. Feeding corn in various forms.—Several trials have been carried on at various stations to determine the most profitable form in which to feed corn to fattening lambs. In trials at the Iowa Station[3] Evvard found that grinding corn was uneconomical, for larger profits and just as rapid or even more rapid gains were secured where ear corn, broken ear corn, or shelled corn was fed. There was also no advantage in feed-

[2]Wis. Rpt. 1897. [3]Proc. Am. Soc. Anim. Prod., 1915-16, pp. 242-51.

ing corn-and-cob meal over feeding ear corn or broken ear corn. One lot of lambs was started on ear corn, changed to broken ear corn as the feeding progressed, and finished on ground corn and broken ear corn; i. e., the preparation of the corn was increased as the lambs fattened. This lot made slightly the largest and most economical gains.

In a trial by Coffey at the Illinois Station[4] lambs fed shelled corn made slightly larger and more economical gains than others fed ear corn. Both ground corn and corn-and-cob meal proved less efficient than shelled corn or ear corn. Paterson likewise found in a trial at the Kansas Station[5] that lambs fed shelled corn made slightly larger gains than others fed ground corn, and also required less feed for 100 lbs. gain and produced a slightly larger profit. In the Illinois trial a lot fed a small amount of shelled corn until they had learned to husk shock corn, but thereafter given corn only in the form of shock corn, made smaller gains than any other lot and required 20 per ct. more corn for 100 lbs. gain than the lot fed shelled corn. Coffey points out that both ear corn and shock corn are better suited for feeding on a thick sod than in a dry lot or barn, for they may be scattered on the sod so that each lamb will have an equal chance to feed and little will be wasted. In the lot or barn, lambs are apt to drop the ears on the ground where they become soiled, or to bunch them up in the trough so that each lamb does not get its share.

From these trials we may conclude that it will rarely pay to grind corn for fattening lambs, except perhaps toward the end of the feeding period, when the lambs are fairly fat, or if it is desired to continue feeding for some time. Some skilled feeders who study the fine points of the feeding game find it profitable to "keep the feed a little better than the lambs," by using coarsely ground corn during the last 30 to 40 days of feeding. As a general rule, however, feeding ear corn or shelled corn may be regarded as the most economical. Coarsely ground corn is preferable to fine meal for sheep or lambs.

Fattening lambs in the corn field, which is a common practice in some localities, is discussed in the next chapter. (**904**)

847. Hominy feed.—Experiments have been carried on at the Kansas, Indiana, and Iowa Stations[6] to find the relative value of hominy feed and shelled corn for fattening lambs. In addition to either corn or hominy feed the lambs were fed clover or alfalfa hay and corn silage, with a small amount of linseed or cottonseed meal in all except the Kansas trial. Averaging together the results of 4 trials, the lambs fed hominy feed gained 0.318 lb. per head daily and those fed corn, 0.325 lb. With hominy feed at the same price per ton as well-cured corn, the feed cost of 100 lbs. gain was practically the same on the two feeds. In trials by

[4]Productive Sheep Husbandry, pp. 375-6.

[5]Kan. Cir. 88.

[6]Skinner, Vestal, and Starr, Ind. Buls. 221, 234; Evvard and Dunn, Iowa Station, information to the authors; Paterson, Kan. Cir. 79.

Gramlich and Savin at the Nebraska Station[7] lambs fed either hominy feed or a mixture of about half hominy feed and half shelled corn, with alfalfa hay for roughage, made more rapid gains than on shelled corn and required less feed for 100 lbs. gain. Especially good results were secured on the mixture of hominy feed and corn. From these trials we may conclude that hominy feed is about equal to well-dried shelled corn per ton for fattening lambs. Obviously, it would be worth more per ton than corn of a high moisture content. (213)

848. Barley.—Thruout the western range district, where but little corn is grown, barley is extensively used for fattening sheep and lambs. (226) In the following table are summarized the results of 6 trials, averaging 96 days, in which brewing or Scotch barley was compared with shelled corn when fed with alfalfa hay to lambs averaging 61 lbs. in weight:

Barley vs. corn for fattening lambs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Hay Lbs.
*Lot I, total of 355 lambs**			
Whole barley, 0.9 lb. Alfalfa hay, 2.4 lbs.....	0.31	296	777
*Lot II, total of 355 lambs**			
Shelled corn, 0.9 lb. Alfalfa hay, 2.3 lbs.....	0.32	283	708

*Average of 3 trials by Faville (Wyo. Buls. 81, 85, 103), 1 by Buffum and Griffin (Colo. Bul. 75), and 2 by Morton (Colo. Bul. 187).

In these trials the lambs fed whole barley made only slightly smaller gains than those fed corn, the former consuming 5 per ct. more grain and 10 per ct. more hay for 100 lbs. gain. With shelled corn at twice the price of alfalfa hay per ton, barley in these trials was worth 16 per ct. less per ton than corn for lambs. In trials by Morton with 450 lambs, Scotch barley proved fully equal to shelled corn in rapidity and economy of gains.

In a trial at the Iowa Station[8] Evvard and Dunn fed a lot of lambs whole barley, corn silage, and clover hay, with enough linseed meal to balance the ration, while another lot received shelled corn in place of barley. Barley produced even larger gains than corn, but the lambs were less highly finished, sold for 40 cents less per 100 lbs., and shrank more on shipment to Chicago. With shelled corn at $1.45 per bushel (14 per ct. moisture basis) barley was worth only 90.4 cts. per bushel, or 27 per ct. less per ton than shelled corn. In a similar trial the next year the lambs fed barley gained nearly as rapidly as those fed shelled corn but again sold slightly lower and shrank slightly more on shipment. In this trial whole barley was worth 20 per ct. less than shelled corn per ton. In a trial at the Kansas Station[9] Paterson and Winchester found barley worth even less in comparison with shelled corn, and Gramlich at the Nebraska Station[10] found barley worth 25 per ct. less per ton than shelled corn, when used to replace one-third the corn in

[7]Nebr. Bul. 173, and information to the authors. [9]Kan. Cir. 88.
[8]Information to the authors. [10]Information to the authors.

a ration of corn and alfalfa hay or a ration of corn, linseed meal, and alfalfa hay.

Considering all the data available, we may conclude that while barley is an excellent feed for fattening lambs, it is worth 18 to 20 per ct. less per ton than shelled corn. California feed barley was found by Morton to have slightly lower value than the heavier Scotch barley, lambs given feed barley requiring 11 per ct. more grain and 4 per ct. more alfalfa hay than those fed Scotch barley.

Altho somewhat richer in protein than is corn, barley is yet a carbonaceous grain and hence gives the best results when fed with legume hay. When fed with carbonaceous hay, the ration should be supplemented with a protein-rich concentrate, such as linseed meal or cottonseed meal.

At the Wyoming Station Faville[11] found that soaking, cracking, or grinding western Scotch barley, which is harder than eastern brewing barley, did not increase its value for lambs. It will probably pay to roll or crack the hard bald or hulless barley, as Faville found that lambs passed more of it undigested than of Scotch barley. If it is ground fine, instead of being cracked or rolled, bald barley is apt to form a sticky mass in the mouths of the sheep. (833)

849. Wheat.—Rarely is wheat fed to sheep unless it is off grade or unusually low in price. (215) To show its value compared with shelled corn, the following table presents the results of 3 trials, averaging 104 days, in which good quality common wheat was compared with corn in lamb-feeding trials.

Wheat vs. corn for fattening lambs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Hay Lbs.
*Lot I, total of 29 lambs**			
Wheat, 1.4 lbs. Hay, 1.5 lbs.....	0.30	524	482
*Lot II, total of 29 lambs**			
Shelled corn, 1.4 lbs. Hay, 1.5 lbs.....	0.30	515	472

*Average of 2 trials by Wilson and H. G. Skinner (S. D. Buls. 80, 86), and 1 by F. B. Mumford (Mich. Bul. 128).

The lambs fed wheat made the same gains as those fed corn, and required only 2 per ct. more grain and hay for 100 lbs. gain. In 4 trials which have been carried on to compare wheat and barley for lambs, wheat has proven of slightly higher value than barley, less being required for 100 lbs. gain.[12] These results, confirmed by British experiments, show that good quality wheat is slightly superior to barley and nearly equal to corn for fattening sheep. Since wheat is a carbonaceous grain, the best results are secured when it is fed with legume hay.

In 2 trials at the South Dakota Station, Wilson and Skinner[13] found durum, or macaroni, wheat practically equal to common wheat for fat-

[11]Wyo. Buls. 89, 103.

[12]Linfield, Mont. Buls. 47, 59; Wilson and Skinner, S. D. Bul. 86; Carlyle and Iddings, Idaho Bul. 77.

[13]S. D. Bul. 86.

tening lambs. Frosted wheat, in a trial by Foster and Merrill[14] at the Utah Station, produced as large and more economical gains than marketable wheat.

850. Wheat screenings.—The value of wheat screenings from the elevators and mills depends on their quality, the light, chaffy grades being more like a roughage than a concentrate. Successful feeders wisely utilize screenings of low grade in getting the lambs on feed, and as fattening advances change to the heavier screenings. Hundreds of thousands of Montana sheep and lambs were annually fed during the nineties on wheat screenings in feed lots near St. Paul, Minnesota. The screenings were fed in sheds and usually from self feeders, as the bits of chaff and straw in the feed render it so bulky that there is less danger of foundering than when corn is fed in self feeders. With the bulky class of screenings which were used, little or no hay was required. During the season of 1902 about 330,000 sheep and lambs were fattened in these feed lots. Two years later the number fell below 200,000, and at the present time this district has ceased to be a factor of importance in the winter mutton supply. Screenings are still employed more or less extensively in other sections of the country for sheep feeding. (**222**)

Trials at the Montana and Utah Stations[15] show that a good grade of heavy wheat screenings may be worth fully as much as good wheat when fed with clover or alfalfa hay. On the other hand, it required 35 per ct. more light-weight, chaffy screenings for 100 lbs. of gain by lambs than of screenings of heavy weight. Screenings should be fed close to the mills or elevators, thereby avoiding large freight bills. As with wheat, the best returns come thru feeding in combination with legume hay. To prevent the spread of weeds, screenings should be ground before feeding.

851. Oats.—This grain, well liked by sheep, is excellent for the breeding flock. (**223, 883**) It is also one of the best feeds to mix with heavier grains, like corn, in starting fattening lambs or sheep on feed. (**899**) However, as oats are bulky and quite high in fiber, they are not well suited to form the chief grain for fattening animals. Therefore, when oats are used in starting lambs on feed, the proportion of this grain is gradually decreased and the oats usually omitted entirely after the lambs are on full feed.

In a trial at the South Dakota Station[16] by Wilson and H. G. Skinner, lambs fed corn with mixed prairie and brome hay gained 0.28 lb. per head daily, while those fed oats in place of corn gained 0.25 lb. The lambs fed oats required 16 per ct. more grain and 10 per ct. more hay for 100 lbs. gain. In two trials at the Iowa Station[17] Evvard and Dunn found that lambs fed oats, clover hay, corn silage, and enough linseed meal to balance the ration, made satisfactory gains compared with others fed shelled corn, but tended to grow rather than fatten,

[14]Utah Bul. 78.

[15]Linfield, Montana Buls. 47, 59; Foster and Merrill, Utah Bul. 78.

[16]S. D. Bul. 86.

[17]Information to the authors.

FRESH PASTURE IS IMPORTANT FOR EWES WITH LAMBS

To avoid infesting the lambs with stomach worms, it is important that fresh, uncontaminated pasture be provided. Winter rye and other winter grains provide good early pasture.

FINE LAMBS ON EXCELLENT CLOVER PASTURE

The clovers furnish valuable pasture for sheep, but great care is necessary to prevent bloat.

LAMBS FATTENING IN A FIELD OF CORN AND SOYBEANS

Many farmers fatten lambs in the fall on rape, stubble fields, or standing corn. Growing soybeans with the corn for "lambing down" is a good practice.

STRAW IS UNSATISFACTORY AS THE ONLY ROUGHAGE

Poor results are secured when lambs are fed straw as the only roughage, but a limited amount of straw may well be used along with legume hay.

and hence sold for a lower price and shrank more on shipment. In these trials oats were worth 33 per ct. less a ton than shelled corn. With shelled corn at $1.45 per bushel, oats had an actual feeding value of only 55 cents per bushel.

To find whether there was any advantage in using oats as part of the concentrates for fattening lambs, J. H. Skinner and King carried on 3 trials at the Indiana Station,[18] in each of which a mixture of about 5 parts oats and 7 parts corn was compared with shelled corn alone, when fed with clover hay and corn silage for roughage. The lambs fed corn as the only grain made slightly more rapid gains and required a little less feed for 100 lbs. gain. In a similar trial at the Nebraska Station[19] Savin found that when oats replaced about one-third the corn in a ration of shelled corn, linseed meal, and alfalfa hay they were worth 23 per ct. less a ton than shelled corn. These trials show that in a well-balanced ration corn is more satisfactory for fattening lambs, after they are on full feed, than a mixture of corn and oats.

Lambs fed clover hay for roughage made nearly as large gains on oats as on barley in 2 trials by Linfield at the Montana Station,[20] but required 6 per ct. more grain and 5 per ct. more hay for 100 lbs. gain. It is unnecessary to grind oats for sheep. (833) As is pointed out in the next chapter, oats are an excellent feed for breeding ewes in the winter. (883)

852. Emmer.—In certain districts of the northern plains states, emmer (wrongly called spelt) has become an important concentrate for sheep and lambs. (233) In 3 trials[21] in which emmer has been compared with shelled corn, alfalfa hay being the roughage, the lambs fed emmer gained 0.28 lb. per head daily on the average, while those fed corn gained 0.31 lb. The lambs receiving emmer required considerably more feed per 100 lbs. gain than the corn-fed lambs. Similar results were secured in 2 trials at the South Dakota Station[22] in which mixed hay was fed as the roughage. Considering the larger amount of both grain and hay required per 100 lbs. gain by the lambs fed emmer, we may conclude that emmer is worth about 75 per ct. as much a ton as corn. In the South Dakota trials emmer had a somewhat higher value when fed with barley or corn, than when used as the sole concentrate.

853. Grain sorghums.—In the southern plains states the various grain sorghums are of great importance for sheep feeding, because they produce satisfactory gains and are commonly considerably cheaper than corn or the other cereals. (235-40) In a trial by Cochel at the Kansas Station [23] grinding kafir did not increase its value for lambs. In 2 trials at

[18] Ind. Buls. 168, 179, 184.
[19] Information to the authors.
[20] Mont. Buls. 47, 59.
[21] Average of 2 trials by Faville (Wyo. Buls. 81, 85), and 1 by Buffum and Griffin (Colo. Bul. 75).
[22] Wilson and Skinner, S. D. Buls. 80, 86.
[23] Information to the authors.

the Texas Station[24] by Jones, Brewer, and Dickson, lambs fed ground threshed milo, with alfalfa hay and a small allowance of cottonseed meal, made just as large and economical gains as others fed ground corn. To equal 100 lbs. of ground corn in feeding value, there were required 103 lbs. of ground threshed kafir, or 107 lbs. of ground threshed feterita. Often grain sorghum is fed in the head, either ground or unground. In these trials it required 107 lbs. of ground milo heads or 116 lbs. of ground feterita heads to equal 100 lbs. ground corn in value. In 3 trials at the Kansas Station,[25] in which whole kafir was compared with shelled corn, the lambs fed kafir made satisfactory gains, tho slightly smaller ones than lambs fed corn.

854. Miscellaneous carbonaceous concentrates.—*Dried beet pulp* produced as large and as economical gains as corn in a trial by Shaw at the Michigan Station[26] in which mixtures of either 4 parts dried beet pulp or 4 of corn, together with 2 parts wheat bran and 1 part linseed meal, were fed with clover hay to western lambs. Humphrey and Kleinheinz of the Wisconsin Station[27] found dried beet pulp equal to corn for producing growth in ewe lambs when oats were fed with both. (**276**)

Molasses-beet pulp showed no marked superiority over ordinary dried beet pulp in a trial by Shaw when 3 parts of either was fed with 1 part of linseed meal, clover hay forming the roughage. Maynard at the Colorado Station[28] found molasses-beet pulp about equal to shelled corn when used as a partial substitute for this grain, in a ration of corn and alfalfa hay. (**278**)

Beet molasses is often fed to sheep and lambs in the vicinity of beet sugar factories in the West. (**277**) To avoid "smearing" the wool, the molasses is preferably mixed thoroly with cut hay or straw. In some cases no other concentrate is fed, and in others wet beet pulp and a little cottonseed cake are added to the ration, or grain is fed in addition to the beet molasses. Maynard found beet molasses to be worth slightly more than corn, pound for pound, when fed to fattening lambs at the rate of 0.3 lb. per head daily, along with corn and alfalfa hay, while in a trial by Hackedorn of the Washington Station [28a] it was worth slightly less per ton than grain.

Cane molasses was found in a trial by Skinner and King at the Indiana Station[29] to be worth no more than an equal weight of shelled corn, when 0.15 lb. per head daily was fed as an "appetizer" along with shelled corn, clover hay, and corn silage, with enough cottonseed meal to balance the ration. Where a small amount of molasses is used to get lambs to clean up rather inferior hay or other dry roughage better than they otherwise would, it would doubtless have a higher value than corn per pound. (**280**)

[24]Tex. Bul. 269; Am. Soc. Anim. Production, Proceedings 1921, pp. 16-21.
[25]Breeder's Gazette, 51, 1907, p. 960; information to the authors.
[26]Mich. Bul. 220.
[27]Wis. Rpt. 1906.
[28]Colo. Bul. 266.
[28a]Information to the authors.
[29]Ind. Bul. 192.

Beet and cane molasses were compared in a trial by Evvard, Sharp, and Culbertson at the Iowa Station,[30] different lots of lambs being fed 0.25 lb., 0.5 lb., and 0.7 lb. beet or cane molasses per head daily. The molasses was poured on corn silage, and the lambs were fed in addition shelled corn, clover hay, and enough linseed meal to balance the ration. The beet molasses proved slightly superior to the cane molasses. It was found that two-thirds to three-fourths pound of molasses was as much as the lambs would take with the other feeds used. The molasses-fed lots made more rapid gains than a check lot receiving no molasses and, on the average, both cane and beet molasses were worth slightly more than shelled corn a ton, considering the amount of feed required for 100 lbs. gain.

Molasses-alfalfa meal (consisting of half alfalfa meal and half molasses) was found to be worth, on the average, but little more than alfalfa hay per ton in 3 trials carried on by Savin at the Nebraska Station,[31] when it was added to a ration of corn and alfalfa hay or one of corn, alfalfa hay, and corn silage. (281)

Millet seed, coarsely ground, was found by Wilson and H. G. Skinner nearly equal to corn for fattening lambs when fed with mixed prairie and brome hay in a trial at the South Dakota Station.[32] Sheep fed whole millet voided a large percentage of the seed undigested. (243)

855. Linseed meal and cottonseed meal.—These protein-rich concentrates are the supplements most commonly used with fattening lambs or sheep, for balancing rations low in protein. (250, 254) In 2 trials by Morrison and Kleinheinz at the Wisconsin Station[33] with western lambs, these supplements were compared when added to shelled corn, a limited amount of legume hay, and all the corn silage the lambs would eat, making a basal ration relatively low in protein. As cottonseed meal is richer in protein than linseed meal, less was needed to balance the ration. Each winter one lot of 40 western lambs was fed a mixture of 1 part cottonseed meal (prime or choice) to 7 parts corn, while another lot was fed 1 part linseed meal to 5 parts corn. Each year there was practically no difference in the gains of the 2 lots, in the amount of feed required for 100 lbs. gain, or in the finish of the lambs. Due to the fact that it was necessary to use slightly less cottonseed meal than linseed meal to balance the ration, the feed cost of 100 lbs. gain was 13 cents less where this supplement was fed.

In trials during 3 years at the Indiana Station[34] by Skinner, Vestal, and Starr, choice cottonseed meal and linseed meal were compared as supplements to a ration of shelled corn, corn silage, and either clover hay or oat straw, equal amounts of cottonseed meal and linseed meal being used. When thus fed, the two supplements had practically the

[30]Information to the authors.
[31]Information to the authors.
[32]S. D. Bul. 86.
[33]Wis. Bul. 275; unpublished data.
[34]Ind. Buls. 221, 256.

same value per ton. In 2 similar trials at the Kansas Station[35] by Paterson and Winchester, linseed meal was worth slightly more per ton than cottonseed meal, when equal amounts were added to a ration of shelled corn, alfalfa hay, and corn or sorghum silage. From these experiments we may conclude that these feeds are both excellent supplements, but that when just enough is fed to balance the ration, choice cottonseed meal is somewhat the more valuable for fattening lambs, because it is richer in protein.

Even when no legume hay, rich in protein, is fed to fattening lambs, no more than one-fourth to one-third pound of linseed or cottonseed meal per head daily is needed to balance the ration. Owing to the poisonous properties of cottonseed meal when fed in excess, a larger amount than this should not be fed to lambs or sheep. In a trial at the Oklahoma Station[36] by Magee and Darlow, lambs fed 0.55 lb. cottonseed meal a head daily, with Sudan hay and darso silage, went off feed after 70 days, while a lot fed a smaller allowance of the cottonseed meal continued to make good gains. In combination with grain, legume hay, and silage, one-eighth to one-fourth pound cottonseed meal will provide a well-balanced ration. Linseed meal is an excellent supplement for the breeding flock, and cottonseed meal is also satisfactory, when not fed in excess. (**883**) Linseed cake and cottonseed cake of nut or pea size are better relished by sheep than finely ground meal.

Cold-pressed cottonseed cake, which contains all the hulls and is consequently lower in protein and higher in fiber than cottonseed meal, was found by Gramlich and Savin in 2 trials at the Nebraska Station[37] to be worth only 72 to 75 per ct. as much per ton as cottonseed meal. (**248**)

856. Other protein-rich concentrates.—*Field peas* and *soybeans* are excellent protein-rich feeds for sheep and lambs, but are commonly expensive. (**261, 256**) Of several concentrate mixtures tested for fitting yearling wethers for shows, the best results in finish of the lambs and firmness of flesh were secured with a mixture of peas, oats, and bran in trials by Humphrey and Kleinheinz at the Wisconsin Station.[38] In a trial by Iddings at the Idaho Station[39] lambs fed 1 part field peas and 3 parts barley, with mixed hay for roughage, gained 11 per ct. less than where pea sized linseed cake was used in place of the peas. The lambs fed peas required 11 per ct. more concentrates and 17 per ct. more hay for 100 lbs. gain than those fed linseed meal.

Soybeans have been compared with choice cottonseed meal as a supplement to shelled corn, corn silage, and clover hay in 3 trials by Skinner and King at the Indiana Station.[40] The lambs fed ground soybeans made only a trifle smaller gains than those fed cottonseed meal and required but little more feed for 100 lbs. gain. In these trials ground soybeans were worth 11 per ct. less a ton than choice cottonseed meal.

[35]Kan. Cir. 88; information to the authors.
[36]Okla. Bul. 133.
[37]Nebr. Bul. 173; information to the authors.
[38]Wis. Rpt. 1905 and Bul. 232.
[39]Idaho Bul. 89.
[40]Ind. Buls. 192, 202, 221.

Wheat bran should form no large part of the concentrate allowance for fattening sheep, for, like oats, it induces growth rather than fattening, and it is too bulky. In a trial by Iddings at the Idaho Station,[41] lambs fed 1 part wheat bran and 3 parts barley, with mixed hay for roughage, gained 0.274 lb. per head daily, while others fed linseed cake in place of bran gained 0.318 lb. daily. When lambs are being started on feed, bran is useful for mixing with corn and other heavy concentrates to forestall digestive troubles. Bran is a valuable feed for breeding ewes. (**218, 883**)

Gluten feed is a satisfactory supplement for fattening lambs, tho it is not commonly thus used. (**210**) As it is considerably lower in protein than linseed or cottonseed meal, a larger amount is needed to balance a ration. In an 84-day trial at the Wisconsin Station[42] by Morrison and Kleinheinz, one lot of 40 lambs was fed 1 part gluten feed and 3 parts shelled corn with corn silage and clover hay for roughage, while another lot was fed 1 part linseed meal and 5 parts corn. The lambs fed gluten feed made practically as large gains as those fed linseed meal, but were not as well finished and shrank more on shipment. With linseed meal at $80 per ton and gluten feed at $72.50 per ton, the profit per lamb was $0.44 greater on linseed meal. In a 30-day trial by Paterson at the Kansas Station,[43] gluten feed was worth 15 per ct. less per ton than linseed meal when fed as the supplement to corn, corn silage, and alfalfa hay.

To determine whether gluten feed could be economically used as a substitute for corn when it is occasionally lower in price than that grain, Dunn and Evvard carried on 2 trials at the Iowa Station.[44] In each trial the lambs fed gluten feed made as large gains as those fed corn, but averaging together the results for the 2 trials, gluten feed proved to be worth slightly less per ton than shelled corn.

Dried distillers' grains and dried brewers' grains, rarely fed to sheep in this country, have given good results in Europe. (**283, 228**)

Peanut meal from partially hulled nuts, containing 36.0 per ct. crude protein and 23.6 per ct. fiber, was slightly superior to linseed meal in a trial by Dunn and Evvard at the Iowa Station[45] when used as a supplement to corn, corn silage, and alfalfa hay. (**258**)

In the same trial *velvet bean feed* (ground velvet beans and pods), containing 17 per ct. crude protein and 14 per ct. fiber, was worth only 60 per ct. as much per ton as linseed meal. (**264**)

Dried blood, fed to young lambs in place of milk at the rate of about 0.5 lb. daily for each 100 lbs. live weight, has given good results in Europe. (**271**)

Flesh meal has been fed with success to sheep in European countries.

Tankage was found by Morrison and Kleinheinz[46] at the Wisconsin

[41]Idaho Bul. 89.
[42]Wis. Bul. 323, pp. 13-15.
[43]Kan. Cir. 88.
[44]Iowa Bul. 185; information to the authors.
[45]Iowa Bul. 185.
[46]Unpublished data.

Station to be readily eaten by lambs when mixed with 9 parts coarsely ground corn. When fed with corn and poor-quality, over-ripe bluegrass hay, both feeds low in protein, 10 per ct. of tankage was as effective as 18 per ct. of linseed meal in balancing the ration. (270)

II. Roughages for Sheep

857. Legume hay.—Hay from the legumes is far superior to any other dry forage for sheep feeding. Fortunately legume hay may be provided in all sections of the country—in the East clover and alfalfa, thruout the West alfalfa with clover and field peas in certain sections, and in the South the cowpea, beggarweed, and other plants. It is more important for sheep than for cattle that the hay be fine-stemmed and leafy.

The superiority of legume over carbonaceous hay for sheep is shown in the following summary of 5 trials, averaging 99 days, in which rations of clover and alfalfa hay with corn as the sole concentrate, have been compared with rations of timothy or prairie hay and corn, with enough cottonseed or linseed meal to balance the ration:

Legume hay vs. carbonaceous hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.
*Legume hay, 71 lambs**				
Clover or alfalfa hay, 1.5 lbs.				
Corn, 1.3 lbs.	63	0.32	388	455
*Carbonaceous hay, 63 lambs**				
Timothy or prairie hay, 1.0 lb.				
Corn, 1.0 lb.				
Cotton- or linseed meal, 0.2 lb.	63	0.24	505	422

*Average of 1 trial by Burnett (Nebr. Bul. 66), 1 by McDonald and Malone (Okla. Bul. 78), 1 by Morton (Colo. Bul. 73), and 2 by Skinner and King (Ind. Bul. 162).

Tho the lambs fed timothy or prairie hay received a well-balanced ration, those on clover or alfalfa made much larger gains and required less feed per 100 lbs. gain. So long as there is an ample supply of good legume hay of any kind, sheep show little desire for other dry roughage.

858. Adding a protein-rich supplement to corn and legume hay.—Fattening lambs given all the corn and legume hay they will eat, consume enough of the protein-rich hay, even toward the end of the fattening period when on a full feed of grain, to balance the ration quite well. Indeed, the rate of gain is usually increased little or even none when a protein-rich supplement, like linseed or cottonseed meal, is added to the ration. In 9 trials at various stations[47] the effect of adding linseed or cottonseed meal to a ration of corn and clover hay has been studied. On the average the lambs fed only corn and clover hay gained 0.313 lb. per head daily, while those fed linseed or cottonseed meal in

[47]Carmichael and Hammond, 3 trials, Ohio Buls. 187, 245; Coffey, 1 trial, Ill. Station, information to the authors; F. B. Mumford, 1 trial, Mich. Bul. 113; Skinner and King, 4 trials, Ind. Buls. 162, 168.

addition gained 0.323 lb. per head daily, an increase of only 0.010 lb. The addition of the supplement did not, however, decrease the amount of concentrates or hay required for 100 lbs. gain.

In 8 trials at the Nebraska[48] and Ohio[49] Stations the effect of adding linseed meal to a ration of corn and alfalfa hay for fattening lambs has been investigated. In these trials the average daily gain of the lambs fed only corn and alfalfa hay was 0.349 lb. and of those fed linseed meal in addition, 0.382 lb., or only 0.033 lb. more. When the linseed meal was fed, slightly less concentrates and hay were required for 100 lbs. gain, so that 100 lbs. of linseed meal saved 88 lbs. of corn plus 45 lbs. of hay. Due to the fact that linseed meal is usually much higher in price per ton than corn, the gains of the lambs fed no linseed meal were usually cheaper.

We may conclude from these trials that it does not generally pay to add a supplement to a ration of only corn and legume hay for fattening lambs. It is pointed out later, however, that it is usually profitable to use a supplement when corn and legume hay are fed with corn silage, as the silage is low in protein. (868)

859. Legume hays compared.—*Red clover,* one of the best roughages for sheep, should be cut early to secure the leaves and heads, which are the portions most desired. (347) The relative value of *alfalfa* and *clover hay* for sheep has been a disputed point. From 4 trials at the Indiana Station,[50] Skinner and King conclude that when fed with shelled corn these hays have practically the same value, if of equal quality. Carmichael and Hammond of the Ohio Station,[51] and Humphrey and Kleinheinz of the Wisconsin Station[52] also found little difference in the value of alfalfa and clover hay. Since alfalfa hay is richer than clover in protein, it undoubtedly has a somewhat higher value than clover when fed in such a ration as corn, corn silage, and hay, with no protein-rich supplements. (338) *Alsike clover hay* proved even slightly superior to alfalfa in a trial at the Montana Station.[53] (350) *Mammoth clover hay* is usually coarser and more stemmy than medium red clover. (349)

Cowpea or soybean hay is excellent for sheep when of good quality. (357, 358) In a trial at the Oklahoma Station[54] cowpea hay proved equal to alfalfa hay, while in a trial at the Kansas Station[55] lambs fed cowpea hay required 14 per ct. more grain and silage and 29 per ct. more hay for 100 lbs. gain than others fed alfalfa hay.

Sweet clover hay was found fully equal to alfalfa hay in a trial by Hackedorn at the Prosser, Washington, Branch Station, and in a trial at the South Dakota Station Wilson found it a palatable and satisfactory

[48]Gramlich and Savin, Nebr. Bul. 173, and information to the authors.
[49]Carmichael and Hammond, Ohio Bul. 245.
[50]Ind. Buls. 179, 184, 192, 202.
[51]Ohio Bul. 245.
[52]Unpublished data.
[53]Mont. Bul. 21.
[54]Okla. Bul. 78.
[55]Information to the authors.

roughage, tho somewhat inferior to alfalfa.[56] (**352**) In the same trial *field pea hay,* while relished by the lambs, produced lower gains than either alfalfa or sweet clover hay. (**355**) *Oat and pea hay* is satisfactory for sheep.

Legume straws are good substitutes for legume hay in sheep feeding, when bright and free from mold, tho of course they are worth considerably less per ton than legume hay. *Field bean straw* is used quite extensively by Michigan sheep feeders. In a trial by H. W. Mumford at the Michigan Station[57] lambs fed bean straw, shelled corn, and rutabagas made satisfactory gains but required considerably more feed for 100 lbs. gain than others fed clover or alfalfa hay. Hence, the bean straw was worth only about half as much a ton as the hay. *Field pea straw* was fed to ewe lambs and ewes in winter by Hackedorn and Ruehl at the Washington Station[58] in comparison with alfalfa hay. Somewhat smaller gains were made on the pea straw, and more grain was required to keep the animals in good condition, but with alfalfa hay at $25 per ton and pea straw at $10 per ton, the cost of wintering was considerably less on the straw. *Soybean straw,* fed with shelled corn and linseed meal, produced fair gains in a trial by Carmichael and Hammond at the Ohio Station,[59] but the straw was worth only about one-third as much a ton as clover or alfalfa hay.

860. Field peas.—The fattening of lambs by grazing on field peas is an important industry in certain sections of the West, especially in the San Luis Valley, Colorado. Mexican peas, similar to the common Canadian field peas, are sown at the rate of 30 to 50 lbs. per acre, with a small quantity of oats or barley to support the vines and furnish additional feed. About November 1, as soon as most of the peas have matured, lambs or sheep are turned into the field, and without other feed are fattened in from 70 to 120 days. An acre of such peas will fatten from 8 to 15 lambs, each making a gain of from 6 to 8 lbs. per month. This system is economical, because there is no expense for harvesting the crop. Confining the lambs to small areas by hurdles gives better results than allowing them to roam over the entire field. Sometimes the peas are cut, stacked, and fed to the lambs in yards. (**355**)

At the Wyoming Station[60] lambs grazed on field peas made larger gains and reached market in better condition than others fed alfalfa and corn. In a second trial Morton[61] found that, altho the gains of lambs fed alfalfa and corn were 50 per ct. greater than those grazed on field peas, the net returns were the same, due to the low cost of producing the peas. In this trial the lambs consumed 0.6 acre of peas for each 100 lbs. gain.

[56]Hackedorn, information to the authors; Wilson, S. D. Bul. 143.
[57]Mich. Bul. 136.
[58]Information to the authors.
[59]Ohio Bul. 245.
[60]Wyo. Bul. 60.
[61]Wyo. Bul. 73.

861. Timothy and other carbonaceous hay.—Hay from timothy and the other grasses is much inferior to legume hay for feeding all classes of sheep, as has been pointed out previously. (**857**) As such hay is low in protein, some protein-rich concentrate, like linseed meal, should always be added to balance the ration. Even then, however, the gains of fattening lambs will be much lower than when legume hay is fed.

Timothy hay is unsatisfactory for sheep, being both unpalatable and constipating. The dry heads of this grass work into the wool, irritating the skin, lowering the quality of the wool, and making shearing difficult. (**312**)

Marsh hay is too coarse and woody for sheep. *Bluegrass hay* and bright *oat straw* are preferable to either of these hays. (**311, 328**) *Millet hay* in a trial at the Michigan Station[62] by H. W. Mumford proved poorer than corn stover or oat straw. More care was necessary in feeding this hay than any other coarse fodder, as it induced scours unless fed in limited quantity. (**317**)

Western *prairie hay,* tho more palatable than timothy hay, is much inferior to alfalfa hay. (**857**) In trials during three years at the University of Alberta, Canada,[62a] by Dowell, Bowstead, and Flack, oat hay proved somewhat superior to prairie hay or timothy hay for fattening lambs, and but slightly inferior to alfalfa hay, when fed with a concentrate mixture furnishing plenty of protein. However, for wintering pregnant ewes fed no grain, alfalfa hay was decidedly better than timothy hay, prairie hay, or oat hay, the last giving the poorest results.

Sorghum hay or fodder ranks with corn stover, the value depending on its fineness and leafiness.

862. Corn stover and corn fodder; straw.—Bright, well-cured *corn fodder* or *corn stover* is preferable to timothy hay for feeding sheep. (**302-4**) By far the best results are secured when these forages form only part of the roughage and some legume hay is fed in addition. For example, in a trial at the Oklahoma Station[63] by McDonald and Malone, lambs fed about half corn stover and half alfalfa hay for roughage, along with shelled corn, made nearly as large gains as others fed all alfalfa hay as the roughage, and required only 5 per ct. more corn and 3 per ct. more roughage for 100 lbs. gain.

Straw should not be fed as the only roughage to sheep, as it is low in nutrients and, moreover, is constipating. A limited amount of straw, especially oat straw, may often be used economically as part of the roughage, along with legume hay and silage, or legume hay without silage. Coffey[64] concludes that if straw of good quality is available at one-third the cost of legume hay, it will pay to feed some of it, even if given no oftener than two or three times a week. Thus fed, it furnishes a helpful change which stimulates the appetite of the animals. Experienced Michigan sheep feeders give oat straw at one feed and

[62]Mich. Bul. 136.

[62a]Information to the authors.

[63]Okla. Bul. 78.

[64]Productive Sheep Husbandry, p. 383.

alfalfa hay at the next, claiming that lambs so fed gain as well as tho alfalfa formed the sole roughage. Shaw[65] advises that when both legume hay and straw or other rather unpalatable roughages are fed, the legume hay should be given for the evening meal. It is pointed out later in this chapter that lambs fed oat straw and corn silage for roughage, with corn and plenty of protein-rich supplement to balance the ration, do not make as large or as economical gains as when legume hay is fed in place of the straw. (869)

III. Succulent Feeds

863. Value of succulent feeds.—One of the chief advantages of succulent feeds, so keenly relished by sheep, is their tonic and regulating effect. Roots are universally fed in large amounts to sheep in Great Britain, and to this fact may be attributed much of the reputation of the British shepherd for producing mutton of the highest quality. As is shown in the following articles, experiments in this country have proved that roots can be successfully replaced by corn silage, which is produced at lower cost in most sections of the United States. (109)

864. Roots.—The value of roots for fattening lambs is shown in the following summary of 5 trials, averaging 113 days, in each of which one lot was fed roots in addition to an already excellent ration of grain (chiefly corn) and either alfalfa, clover, or mixed clover and timothy hay.

Value of roots for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain		
			Grain Lbs.	Roots Lbs.	Hay Lbs.
*Roots, total of 41 lambs**					
Roots, 3.7 lbs.					
Hay, 1.4 lbs.					
Grain, 1.4 lbs.	81	0.39	374	940	358
*No roots, total of 41 lambs**					
Hay, 1.7 lbs.					
Grain, 1.5 lbs.	82	0.32	456	...	525

*Average of 3 trials by Kennedy, Robbins, and Kildee (Iowa Bul. 110), 1 by Smith and Mumford (Mich. Bul. 113), and 1 by Arkell (N. H. Bul. 152).

In these trials the allowance of roots—mangels, sugar beets, rutabagas, or turnips—ranged from 1.9 to 5.0 lbs. per head daily, the average being 3.7 lbs. The lambs fed roots ate 0.1 lb. less grain and 0.3 lb. less hay per day but made 0.07 lb. larger daily gain. It is noteworthy that in each of the 5 trials the root-fed lambs made the larger gains. In these trials 100 lbs. of roots replaced 8.7 lbs. of grain and 17.7 lbs. of hay.

Rutabagas and mangels are the roots most commonly used for sheep feeding. (365-74) Where the summers are too hot for rutabagas to thrive, as in the central corn belt, mangels or sugar beets are preferable. Turnips are good for fall feeding, and cabbage is highly esteemed in fitting sheep for shows. When fed to sheep, mangels and sugar beets tend

[65] Management and Feeding of Sheep, p. 212.

to form calculi, or stones, in the kidneys and bladder, which may cause death in the case of rams and wethers.[66] Therefore these roots should not be fed to males for long periods, but ewes are not thus affected.

865. Lessons from Great Britain.—The value of succulent feed in the form of roots for sheep fattening is well shown in the compilation made by Ingle of the results of sheep-feeding trials reported in Great Britain[67] from 1844 to 1905, numbering 194. From his extended report the following typical examples show the use British farmers make of roots in fattening sheep and lambs:

Rations used by British farmers in fattening sheep and lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Total gain per head Lbs.
Oxford-Hampshire lambs, fed 87 days			
Roots, 5.7 lbs. Kohlrabi, 11.2 lbs. Clover hay, 0.38 lb. Linseed cake, 0.7 lb.	117	0.48	43
Leicester-Blackfaced lambs, fed 105 days			
Swedes, 15.3 lbs. Hay, 0.7 lb. No concentrates	80	0.21	22
Oxford lambs, fed 102 days			
Swedes, 22.9 lbs. Linseed cake, 0.3 lb. Hay, 0.4 lb. Barley, 0.3 lb.	107	0.43	42
Cotswold yearlings, fed 121 days			
Roots, 15 lbs. Hay, 1.0 lb. Cottonseed cake 1.6 lbs	111	0.33	41
Leicester-Blackfaced lambs, fed 63 days			
Swedes, 19.3 lbs. Dried dist. grains, 0.5 lb.	72	0.39	25
Leicester-Blackfaced lambs, fed 105 days			
Swedes, 12.8 lbs. Linseed cake, 0.7 lb.	81	0.36	37

Not only is the large allowance of roots noteworthy, but also the almost universal use of oil cake—linseed or cottonseed. The gains reported in the first trial are surprising, considering that the only concentrate fed was 0.7 lb. linseed cake per head daily. In the second trial fair gains were secured on swedes and hay alone. In the last 2 trials the lambs fed no dry roughage, but only roots and dried distillers' grains or linseed cake, made excellent daily gains.

Altho these British trials show that large amounts of roots may be safely fed to sheep, it is not ordinarily profitable in this country to feed over 4 to 5 lbs. per head daily, and even half this allowance, preferably pulped or sliced, will furnish the needed succulence in the ration.

866. Corn silage vs. roots.—Owing to the low cost of producing corn silage, the possible substitution of this succulence for roots is a question of prime importance. The following table summarizes the results of 7 trials, averaging 116 days, in which corn silage and roots (sugar beets, mangels, rutabagas, or turnips) were compared, when fed with concentrates and legume or mixed hay:

[66]Iowa Bul. 112.

[67]Trans. Highl. and Agr. Soc. Scotland, 1910.

Corn silage vs. roots for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Succulence Lbs.
*Silage, total of 72 lambs**					
Corn silage, 3.0 lbs.					
Hay, 1.3 lbs.					
Concentrates, 1.2 lbs.	89	0.30	396	439	1,040
*Roots, total of 90 lambs**					
Roots, 4.6 lbs.					
Hay, 1.5 lbs.					
Concentrates, 1.2 lbs.	89	0.32	380	471	1,507

*Average of 3 trials by Grisdale (Ottawa Expt. Farms Rpts. 1910, 1911, 1912), 2 by Kennedy, Robbins, and Kildee (Iowa Bul. 110), and 2 by F. B. Mumford (Mich. Buls. 84, 107).

The lambs fed silage made the same gains in 2 of the trials, larger gains in 1, and somewhat smaller gains in the other 4 trials. On the average there was only 0.02 lb. difference in the daily gains of the lambs fed silage and roots. The silage-fed lambs required 16 lbs. more grain, but 32 lbs. less hay for 100 lbs. gain than those fed roots, the larger requirement of grain by the silage-fed lambs being offset by the larger consumption of hay by those fed roots. Thus, based on the feed required per 100 lbs. gain, 1,040 lbs. of silage replaced 1,507 lbs. of roots, due to the more watery nature of the roots. (**366**)

867. Corn silage.—Only in recent years has the value of corn silage for cheapening the cost of fattening sheep been appreciated. The benefits from adding silage to an already excellent ration are shown in the following average of 8 trials, lasting from 70 to 105 days, in which a ration of clover hay and shelled corn was compared with one of corn silage, clover hay, and shelled corn for fattening lambs.

Value of corn silage when added to well-balanced ration

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs.	Silage Lbs.
*Lot I, total of 172 lambs**					
Corn silage, 1.35 lbs.					
Clover hay, 0.95 lb.					
Shelled corn, 1.15 lbs.	61	0.316	366	308	428
*Lot II, total of 172 lambs**					
Clover hay, 1.57 lbs.					
Shelled corn, 1.24 lbs.	61	0.313	397	507	...

*Average of 5 trials by Skinner and King (Ind. Buls. 162, 168, 179, 184 and 192), and 2 by Coffey of the Ill. Station (Information to the authors).

On the average, the lambs fed silage ate 0.62 lb. less hay and 0.09 lb. less corn daily yet gained slightly more than those fed clover hay and shelled corn. Adding silage to a ration of clover hay and corn does not, however, always result in increased gain, for in 4 of these trials the lambs fed no silage made the larger gains. The great advantage in feeding silage lies in the saving of corn and hay required for 100 lbs. of gain. In these trials 1 ton of corn silage saved 144 lbs. of corn and 930 lbs. of

clover hay. From this, one can readily compute the value of corn silage with shelled corn and clover hay at local prices. For example, with corn at 56 cents a bushel and clover hay at $14 a ton, corn silage would have a value of $7.95 per ton, which is much more than the cost of production on most farms. (410) Besides lowering the cost of the gains in these trials, the addition of silage to the ration usually resulted in higher finish and consequently in a greater selling price. (296, 411)

The value of corn silage for fattening lambs is further shown by the results of 6 trials at the Nebraska, Kansas, and Indiana Stations[68] in each of which one lot of lambs was fed shelled corn and alfalfa hay, while good-quality corn silage was added to the ration of another lot. The lambs fed corn silage in addition to corn and alfalfa hay gained on the average 0.346 lb. per head daily, which was a trifle less than where no silage was fed. Tho the silage did not increase the rate of gain in these trials, 1 ton of silage saved 82 lbs. corn and 665 lbs. alfalfa hay. With shelled corn at 56 cents a bushel and alfalfa hay at $15 a ton, this would give corn silage a value of $5.83, a high value, tho somewhat lower than obtained in the trials previously reviewed where corn silage was added to corn and clover hay.

It is shown in the next chapter that corn silage of good quality is as valuable for the breeding flock as for sheep being fattened for market. (884) The numerous instances in which sheep of all classes have died from eating moldy or decayed silage point out that greater care is necessary in feeding silage to sheep than to cattle. As sour silage is apt to cause colic and scouring, silage for sheep should be made from well-matured corn.

868. Adding a supplement to silage, corn, and legume hay.—It has previously been shown that adding a nitrogenous concentrate, such as linseed or cottonseed meal, to an already well-balanced ration of corn and legume hay is not ordinarily profitable. (858) However, when lambs are full fed on silage in addition to corn and legume hay, they will not eat enough of the hay to balance the ration. Adding a supplement will then materially increase the gains.

Skinner and King[69] conducted trials during 5 successive years at the Indiana Station with 60-lb. lambs to determine whether it would be profitable to add a nitrogenous concentrate (cottonseed meal) to a ration of shelled corn, corn silage, and clover hay. The results of these trials are averaged in the following table. In each trial one lot of lambs was fed a mixture of 1 part cottonseed meal and 7 parts shelled corn with corn silage and clover hay, while another was fed no cottonseed meal:

[68]Gramlich and Savin, Nebr. Stations, 4 trials, Bul. 173 and information to the authors; Paterson and Winchester, Kan. Station, 1 trial, Cir. 88; Skinner and King, Ind. Station, 1 trial, Bul. 202.

[69]Ind. Buls. 162, 168, 179, and 184.

Adding a supplement to a ration of corn, corn silage, and clover hay

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Nutritive ratio
Lot I, supplement Cottonseed meal, 0.16 lb. Shelled corn, 1.1 lbs. Corn silage, 1.3 lbs. Clover hay, 1.0 lb.....	0.355	348	287	368	1:6.8
Lot II, no supplement Shelled corn, 1.2 lbs. Corn silage, 1.2 lbs. Clover hay, 1.0 lb.....	0.331	360	299	379	1:8.8

Adding the protein-rich cottonseed meal to the shelled corn, corn silage, and clover hay, increased the gains and slightly lessened the amount of feed required for 100 lbs. gain. This shows that the ration of shelled corn, corn silage, and clover hay, which had a nutritive ratio of 1:8.8, was too wide for maximum gains with fattening lambs. In these trials 100 lbs. of cottonseed meal saved on the average a total of 127 lbs. shelled corn, 27 lbs. clover hay, and 11 lbs. corn silage. Also, on the average the lambs fed cottonseed meal reached a slightly higher finish than those fed no supplement and sold for 5 cents more per 100 lbs.

In 6 similar trials at the Iowa, Kansas, and Nebraska Stations[70] the addition of linseed meal to a ration of shelled corn, corn silage, and alfalfa hay increased the average daily gain of lambs from 0.278 lb. per head daily to 0.320 lb. In these experiments 100 lbs. of linseed meal saved on the average a total of 120 lbs. shelled corn, 163 lbs. corn silage, and 122 lbs. of alfalfa hay. The average cost of feed per 100 lbs. gain was 78 cents less for the lambs fed linseed meal, the average selling price per cwt. 32 cents higher, and the average profit per head 42 cents more. It was therefore profitable under usual conditions to add the supplement to the ration of corn, corn silage, and alfalfa hay.

When linseed meal, cottonseed meal, and other supplements are unusually high in price compared with grain, it may be most profitable to omit the supplement, for, if good quality legume hay is fed, the lambs will make quite satisfactory gains on only corn, legume hay, and silage.

Skinner and King found in other trials that with clover hay and corn silage for roughage, fattening lambs made almost as rapid gains when fed 1 part of cottonseed meal to 7 parts of corn, which gave a nutritive ratio of 1: 6.8, as they did when fed 1 part of cottonseed meal to 4 parts of corn, which gave a nutritive ratio of 1: 6.1. Furthermore, the gains were usually cheaper when the smaller allowance of cottonseed meal was fed. This indicates that for fattening lambs a ration having a nutritive ratio of 1: 6.8 is about as satisfactory as the narrower ratio of 1: 6.1. When legume hay does not form part of the roughage, the pro-

[70] 1 trial, Dunn and Evvard, Iowa Bul. 185; 2 trials, Paterson and Winchester, Kan. Cirs. 79 and 88; 3 trials, Savin, information to the authors.

portion of supplement should be increased accordingly, so as to provide a well-balanced ration.

869. Amount of silage to feed.—When corn silage was first used for fattening lambs, many believed that better results would be secured if the allowance of silage was limited, instead of allowing the lambs to eat all of the silage they wished. This question was studied in 3 trials by Skinner and King[71] and in 2 trials by Coffey.[72] In each trial one lot of lambs was fed all of the silage they would clean up twice a day in addition either to clover hay and shelled corn, or to clover hay, corn, and cottonseed meal. Another lot was fed the same ration, except that the amount of silage was limited. The largest allowance of silage produced the most rapid, and, with feeds at the usual prices, the cheapest gains. Also it produced just as good or better finish.

These trials show clearly that it is most profitable to feed fattening lambs all the silage they will eat. However, succulent feed should not ordinarily form the only roughage. The results of 7 trials carried on at the Indiana Station[73] by Skinner, King, Vestal, and Starr show that it is decidedly more profitable to feed legume hay in addition. In each of these trials one lot of lambs was fed corn silage as the only roughage, along with shelled corn and cottonseed meal, while another lot was fed clover hay in addition. In every trial the lambs fed only corn silage for roughage made much smaller gains, had poorer appetites, and required more care to prevent going "off feed." In fact, in most of the trials, it was neccessary to feed a little clover hay at times to get them back on feed. In all but two trials the gains were considerably cheaper when clover hay was fed, and in each trial the profit was greater. Even when the lambs fed corn silage as the only roughage made cheaper gains, this was more than offset by their poorer finish and lower selling price.

Unlike the results with steers (**778**), the appetite of lambs for dry roughage was not satisfied by supplying oat straw in addition to silage, even when plenty of protein was furnished by increasing the amount of cottonseed meal. Neither did feeding clover hay only every fifth day prevent the lambs going off feed. We may therefore conclude that it is best to supply legume hay to fattening lambs, in addition to all the silage they will clean up both morning and evening. It is interesting to note that lambs given all the silage they care for will still eat nearly as many pounds of hay as of silage, while on similar feed steers eat 5 to 7 times as many pounds of silage as hay. (**776**)

870. Silage other than corn.—*Sorghum silage,* both from the sweet sorghums and from the grain sorghums, is satisfactory for sheep when made from plants sufficiently mature to produce silage low in acidity. (**309**) Such silage is of great importance to sheep men in the western semi-arid districts. In a trial by Cochel at the Kansas Station,[74] lambs

[71] Ind. Buls. 162, 168, and 179.
[72] Information to the authors.
[73] Ind. Buls. 168, 179, 184, 192, 202, 221, and 234.
[74] Information to the authors.

fed sweet sorghum silage with alfalfa hay and either corn or kafir grain gained 0.35 to 0.40 lb. per head daily—excellent gains.

In certain districts of the west, where the climate is too cool or too dry for corn, *sunflower silage* has recently come into prominence as a feed for sheep. (**384**) Hackedorn of the Washington Station[75] found that lambs fed sunflower silage with pea straw, barley, and beans made considerably smaller gains than another lot fed corn silage in place of the sunflower silage. No difficulty was experienced in getting the lambs to eat the sunflower silage and they wasted little. Sunflower silage gave good results when fed with pea straw to breeding ewes. Joseph also secured satisfactory results with sunflower silage for breeding ewes in a trial at the Montana Station.[76] One lot of 15 ewes was fed a ration of 2.2 lbs. sunflower silage, from plants harvested when 30 per ct. were in full bloom, and 3.0 lbs. alfalfa hay, with oats in addition for 20 days before the lambing season. Another lot was fed alfalfa hay without silage. Both lots were maintained in satisfactory condition. In this trial it took 2.5 lbs. sunflower silage to replace 1 lb. of alfalfa hay. On the other hand, in other trials sunflower silage has been decidedly inferior to sorghum silage or to pea and barley silage.[77]

Field pea silage is an excellent feed for sheep, where peas flourish. (**355**) In the vicinity of pea canneries fattening sheep and lambs on ensiled pea vines and pods is an important industry, especially in Wisconsin. (**356**) Some dry roughage, such as corn stover or hay, is supplied in addition to the silage, and grain or screenings fed, especially during the latter part of the fattening period. For example,[78] one winter one man fed about six thousand 59-lb. lambs for an average of 94 days on a ration of 1.6 lbs. of grain, chiefly corn and screenings, 3.5 lbs. pea vine silage, and a small allowance of hay. The lambs gained 0.30 lb. per head daily on the average, requiring 541 lbs. grain and 1,147 lbs. silage for 100 lbs. gain.

Pea and oat silage proved practically equal to corn silage for fattening lambs in a trial by Iddings and Hickman at the Idaho Station.[79] *Pea and bald barley silage* was worth $5.05 a ton for fattening lambs in a trial by Potter and Withycombe of the Oregon Station,[79a] with alfalfa hay at $8 and barley at $25 a ton.

871. Wet beet pulp.—This by-product is extensively fed to fattening sheep in the vicinity of the beet-sugar factories in the western states. (**275**) Because the pulp is a cheap feed, the sheep are commonly given all they will eat, along with alfalfa hay. This admirably supplements the pulp, which is low both in protein and lime. Feeding a limited allowance of corn, barley, or other grain in addition is usually advis-

[75]Information to the authors.

[76]Information to the authors.

[77]Barlow, Breeder's Gazette, 80, 1921, p. 183; Potter and Withycombe, Ore. Bul. 184.

[78]Country Gentleman, 79, p. 808.

[79]Information to the authors.

[79a]Ore. Bul. 184.

able. In a trial at the Colorado Station[80] Maynard found that when beet pulp was added to a ration of corn and alfalfa hay, the gains of the lambs were slightly increased, and one ton of beet pulp replaced 222 lbs. of shelled corn plus 208 lbs. of alfalfa hay in putting on gains.

In a trial at the Utah Station[81] Linfield found that lambs fed only 3.7 lbs. wet beet pulp and 1.6 lbs. alfalfa hay per head daily, without any concentrates, made an average daily gain of only 0.21 lb. Another lot fed 0.5 lb. wheat screenings and bran in addition to wet beet pulp and alfalfa hay gained 0.33 lb. per head daily. Each 100 lbs. of grain fed effected a saving of 495 lbs. of wet beet pulp and 240 lbs. of alfalfa hay. In another trial feeding 0.4 lb. grain per head daily with pulp and hay produced practically as rapid and decidedly cheaper gains than feeding 0.9 lb. grain.

Wet beet pulp is especially suitable for fattening aged ewes with poor teeth. In feeding the watery pulp, it is important that the yards be kept dry by proper drainage and the use of bedding.

872. Pastures.—Owners of farm flocks rely mainly on permanent pastures for furnishing pasturage from spring to autumn. In fact many sheep raisers place far too much confidence in such pastures, and fail to appreciate their limitations. In the humid regions care is always necessary to prevent infestation with stomach worms when permanent pastures are used. Moreover, the flock will often run short of feed in time of midsummer drought, unless temporary pastures are provided in the manner discussed later. As sheep relish weeds and browse eagerly on sprouts and brush refused by other stock, small farm flocks can glean much feed from such sources and at the same time help in cleaning up the farm, especially lanes and fence corners. The wise flockmaster will always fully utilize all such feed, including stubble and stalk fields and the aftermath on meadows, in this manner reducing the cost of feed. Sheep prefer reasonably short grass to rank growths, and will eat weeds much better while they are young.

Of the permanent pastures, bluegrass is the most common in the upper Mississippi valley and eastward. (**311**) Timothy furnishes good early pasture, but is not very palatable after heading out. (**312**) Farther south red top is prominent, and in the southern states Bermuda grass. (**314, 320**) In the West the native grasses, especially the grama species, furnish much of the grazing on the ranges, tho on mountain ranges in Idaho, Beattie of the Washington Station[82] found the food mostly herbs, and the leaves and twigs of shrubs.

The clovers furnish valuable pasture, but great care is necessary to prevent bloat when sheep are grazed on them. (**348**)

Caution should always be used in putting sheep onto clover or rape pasture, as both often cause bloat, which may prove fatal. When beginning to pasture these forages, the sheep should be allowed to graze but a short time the first day, and the period gradually increased till

[80]Colo. Bul. 266. [81]Utah Bul. 78. [82]Wash. Bul. 113.

after a week they may remain continuously on the pasture. It is well to allow sheep to satisfy their hunger largely on other pasture or with hay or grain, before turning them on these crops. Even when care is taken, animals occasionally bloat, especially on sultry days following a rain. Immediate attention is then necessary to save the afflicted ones. Kleinheinz[83] of the Wisconsin Station recommends a drench of a pint to a quart of milk warm from the cow. Others place a stick in the animal's mouth, tied back of the head with a string, or resort to the trocar or knife.

Alfalfa is especially liable to cause bloat and can be recommended as a pasture plant for but few sections, altho some skillful flockmasters suffer little loss. In some sections of the West alfalfa is utilized for winter grazing, as it is then so lacking in succulence that danger from bloat is practically absent. (340)

873. Annual pastures.—Occasionally sheep are grazed chiefly on annual pastures especially sown for them. This system is usually more expensive under American conditions than a combination of permanent pastures and annual grazing crops. The advantages of the system are that it enables the flockmaster to maintain more animals on a given area than otherwise; it favors rapid, continuous gains by providing succulent pasture from spring to fall; it destroys nearly all kinds of weeds; and it uniformly fertilizes the land. In this system grass pasture should be available during wet seasons, especially on heavy soils.

On British farms heavily stocked with sheep, a rotation of grazing crops carries the ewes and lambs from the first of the season until weaning, after which the ewes go on old grass land and the lambs to freshly seeded land or other green crops.[84] Lands newly seeded to grass and clover can be successfully pastured by sheep, provided they are kept off when the ground is soft from rain, and if they are not allowed to crop the young plants too closely.

874. Supplementary grazing crops.—The best shepherds commonly follow the practice of using various annual crops to supplement permanent pastures. The earliest grazing is usually furnished by the cereals, of which winter rye is the best for the northern states. Rye is also grown for fall grazing. Farther south winter wheat and winter oats are excellent grazing crops for the colder months.[85] (318) The sorghums are useful in the plains region, altho not especially relished by sheep. Where they flourish, field peas, vetches, cowpeas, soybeans, crimson and Japan clover, and velvet beans all furnish excellent grazing. (355, 359, 357, 358, 353, 360, 361) Rape is the most widely useful member of the mustard family, which furnishes several other grazing crops. (381) Kale provides excellent spring feed in the mild climate of the Pacific coast, where it endures the winter. (382) In the fall kohlrabi and cab-

[83]Sheep Management, Breeds, and Judging, pp. 120-3.

[84]Craig, Sheep Farming, p. 206.

[85]Marshall and Potts, U. S. D. A., Famers' Bul. 1181.

bage may be useful. (379-80) Both rutabagas and turnips are widely grown in Great Britain for grazing. Shaw suggests that these crops should be profitable for winter grazing in the southern states. (370-1) It is pointed out in the next chapter that the fattening of lambs in corn fields is a growing practice. (904) Usually rape is seeded in the corn fields at the last cultivation or soybeans may be grown with the corn.

875. Rape.—Thruout the northern states, rape is more widely grown for sheep than any other annual pasture crop. (381) If sown early, it will furnish good grazing before the lambs are old enough for market. Rape should not be pastured until it has reached a height of 6 to 10 inches, and it should be borne in mind that grazing the crop too closely will kill the plants before the end of the growing season.

As rape may cause bloat in sheep, the precautions previously mentioned should always be taken in pasturing this crop. (872) Allowing lambs to graze on rape when it is wet or too immature may cause scours. It is best to keep sheep, and especially lambs, off from a field of rape drenched with dew or rain until the leaves are dry. Often flockmasters cut rape and feed it as soilage, instead of using it as a pasture crop. This is safer, but takes considerable labor. Rape may be pastured late in the autumn, even after it freezes, providing the sheep have been accustomed to it before it freezes. Otherwise the frozen rape may cause some deaths.

As Coffey points out,[86] three methods are commonly used in growing rape for fall feeding. First it may be seeded as the sole crop; second, it may be sown with oats at the rate of 2 lbs. of rape seed to the acre; and third, it may be seeded in corn at the last cultivation at the rate of about 3 lbs. per acre. When there is sufficient moisture, rape sown in oats grows rapidly after the oats are cut and furnishes feed that is ready to be pastured by the first of September. A good growth of rape in corn depends on seeding early, on the supply of moisture and on the density of the corn foliage, but if the corn is to be pastured with sheep, it usually pays to sow rape, for around the edges of the field at least there will be a good growth of it, which will be large enough for pasturing by the middle of September or the first of October. (904)

To determine the value of rape for lambs, Shaw grazed 3 lots of 71-lb. lambs on rape at the Ontario Agricultural College.[87] Each lot of 15 lambs was grazed for 58 days on an acre of rape. One lot, which received no other feed, gained 0.39 lb. per head daily and the acre of rape produced 344 lbs. of gain on the lambs. A second lot, which had the run of a grass pasture adjoining the rape plot, gained 0.47 lb. per head daily, showing a decided advantage for the combination of grass and rape. A third lot fed 0.5 lb. oats a head daily made but little better gains than the lambs on rape alone. The question of feeding grain to lambs on pasture is discussed in detail in the following chapter. (896)

[86]Productive Sheep Husbandry, p. 388. [87]Ont. Agr. Col. Rpt. 1891.

876. Annual vs. permanent pastures.—It will commonly be found that lambs grazed on annual pastures, such as rape, will make more rapid gains than where the entire reliance is placed on such permanent pastures as bluegrass. For example, in a trial by Craig at the Wisconsin Station[88] lambs grazed on rape pasture and fed 0.7 lb. grain per head daily in addition gained 0.37 lb. each daily, while others fed the same amount of grain on bluegrass pasture gained only 0.24 lb. When the lambs were later removed from pasture and fattened in feeding pens, the lambs which had been on rape continued to make somewhat larger and more economical gains, due to better thrift. In trials by Hammond of the Ohio Station[89] rape or a succession of rye, clover, and rape produced somewhat more rapid gains and better finish on lambs than bluegrass pasture. Rape pasture was worth 3 to 4 times as much per acre as the bluegrass pasture. Sometimes unsatisfactory results are secured with rape, because it may[90] cause scours.

Commonly the best system of flock management is to use annual pastures to supplement the permanent pastures. As is pointed out in the next chapter, the greatest need for such additional feed comes when the lambs are weaned. At this time some fresh pasture crop, uncontaminated with parasites, should always be provided to furnish an abundance of palatable, succulent, and nutritious feed.

[88]Wis. Rpt. 1897.
[89]Ohio Bul. 340.
[90]Nebr. Bul. 170.

CHAPTER XXXII

GENERAL CARE OF SHEEP AND LAMBS—FATTENING—HOT-HOUSE LAMBS—GOATS

I. The Breeding Flock

Order, regularity, and quiet are of prime importance in the management of sheep. The flock should always be cared for by the same attendant, who moves among them quietly, giving notice of his approach by speaking in a low voice and closing doors and gates gently. Dogs and strangers should be kept from the pens at all times. Cleanliness is essential, for the sheep is the most dainty and particular of all farm animals. The successful shepherd is therefore gentle, patient, punctual, and cleanly at all times in the care of his flock.

877. The ewe flock.—Autumn is the time when the beginner in sheep husbandry usually makes his start, and when preparations for the succeeding lamb crop are made in flocks already established. Before the breeding season in the fall, all ewes should be discarded which are non-breeders or poor milkers, and also those with broken mouths or spoiled udders, and any which are too old or otherwise past their usefulness. Those kept should not be selected by looks alone, for the thinnest ones may have been brought to this condition by a heavy milk flow. As a rule a good ewe should be retained as long as she will breed. In farm flocks most of the ewes are commonly disposed of at the age of 6 to 7 years. Those sold should be replaced by the yearlings picked as most promising the preceding fall, while still lambs. Ewe lambs should not be bred in the fall, else their growth will be stunted.

878. Date of lambing; gestation period.—In farm flocks it is much more profitable to have the lambs come in late winter and early spring, rather than later, provided warm quarters are available for lambing time. Early lambs have a better chance of securing proper attention from the flock owner than those which are dropped later, when other farm work is pressing. By the time pasture is ready in the spring, the lambs have learned to eat grain and are old enough to make the most of the fresh grass and genial sunshine. Early lambs are also troubled less by stomach worms than those which come later. Finally, early lambs raised on the farm may be fattened and sold before the market is flooded with western range lambs from the feed lots, causing a fall in the price. If warm quarters can not be provided for lambing, lambs should not be dropped earlier than May in the northern states, and not until the dams are at pasture.

The most extensive data on the gestation period of ewes are those

compiled by Humphrey and Kleinheinz from the records of the flock at the Wisconsin Station,[1] consisting mainly of ewes of the English breeds. The gestation period for 1,142 ewes ranged from 140 to 156 days, the average being 147 days. The greatest number (19 per ct.) dropped their lambs on the 146th day, followed by the 147th and 145th. Over half the entire number yeaned on these 3 days. Tessier of France[2] reports that the average gestation period of 912 ewes, doubtless of the Merino breed, was 152 days, over 75 per ct. lambing between the 150th and 154th days. This agrees with the Wisconsin records, which show that the Merino and Cheviot ewes carried their lambs longer than those of the English breeds. Also, the gestation period for Shropshires and Southdowns was shorter than for the larger English breeds.

879. Flushing the ewes.—Experienced shepherds have found that ewes which are gaining rapidly in flesh at breeding time are more apt to produce twins and triplets than those in poor flesh. Ewes bred when in a thrifty condition are also more reliable breeders and more certain to produce vigorous lambs. Accordingly, with the farm flock, it is advisable to "flush" the ewes for 2 to 3 weeks before the desired date of breeding; i. e., to supply an abundance of palatable, nutritious feed, such as rape, cabbage, good pasture, or grain. This is especially needed if the ewes have run down in flesh during summer, as is common with ewes having large milk flows, even tho they have had good care and pasture. Another advantage of flushing the ewes is that the flock will all breed within a briefer time, thus shortening the lambing period with its anxious hours. Flushing the ewes is a common practice with English flockmasters.

Where the ewes and lambs are well fed, twin lambs will make nearly as rapid gains in weight as single lambs.[3] Therefore twins are advantageous under favorable farm conditions. On the other hand, on the western range where but little attention can be given to the individual ewes, single lambs have given the best results.

880. The ram.—A well-built, vigorous pure-bred ram should be chosen and then be so fed and cared for that he will remain virile. He needs no grain while on good pasture during summer, but beginning at least a month before breeding time some concentrates should be fed. During the breeding season he should be kept in good condition by feeding at least 1 lb. a day of a mixture fairly rich in protein, such as 3 parts of oats and 1 of wheat bran. This amount is for a ram of average size. The ram should never be allowed to run down in breeding season thru insufficient feed or over use. On the other hand, he should never become fat. In purchasing, avoid a ram that has been fitted for shows, for such high living tends to result in impotence.

During the breeding season the ram should run with the ewes but a short time daily, or at night only, unless he is of very nervous tem-

[1]Unpublished data. [3]Craig, Wis. Rpt. 1899, Ritzman, N. H. Tech. Bul. 14.
[2]Coleman, Sheep of Great Britain.

perament and frets all the time when away from the flock. Where "hand coupling" is not practiced, to determine whether a ewe has been bred and at what time, the ram should be painted on the brisket with some compound which will leave a mark on the wool of the ewe. A vigorous ram will serve 35 to 50 ewes a season, if allowed to run with them all the time. Where "hand coupling" is practiced or the ram is turned with the ewes only a short time daily, 50 to 75 ewes may be bred to one ram.

In winter the ram may be kept in thrifty condition on 0.5 to 1.0 lb. of concentrates a day, with good roughage. Some succulent food is desirable, but mangels and sugar beets should be avoided. (**864**) Ram lambs need a liberal ration containing plenty of protein but should not be allowed to become fat. Lack of exercise injures the ram's procreative powers. Except during mating time the ram should be kept away from the ewe flock, so that he cannot annoy them.

881. The flock in winter.—Before going into winter quarters, it is advisable, especially in large flocks, to divide the flock into groups of the same size, sex, strength, and general characteristics. To give the highest returns a division of mutton sheep should not contain over 50 members. Each member will then have an equal chance with its fellows at the feed trough and in enjoying attentions from the shepherd's hand, and the ration may then be adapted to the special needs of each group.

The quarters for the flock in winter should be dry, well-ventilated, and sunny. Drafts must be avoided, or trouble is sure to result. Warm quarters are not only unnecessary, but inadvisable. (**830**) From 10 to 15 square feet of ground space should be provided for each ewe. There should be wide doorways, lest the animals suffer injury when all attempt to rush thru at once, in true sheep fashion. Conveniently placed feed racks should furnish 15 to 24 inches of space per head. Salt and plenty of water should always be provided for the flock, as has been pointed out previously. (**837, 838**)

To insure a crop of strong, healthy lambs, exercise for the ewes is essential. In winter the flock should have access to a dry, sunny yard, well protected from wind and storm. To force the ewes to exercise on all fair days, roughage may be scattered in small bunches over a nearby field. If the snow is deep, paths should be broken out with snow plow or stone boat. On stormy days the sheep should remain indoors, for wet fleeces dry but slowly in winter.

882. Fall and winter feed for breeding ewes.—Quite commonly stubble and stalk fields can form the chief feed for the band of ewes in the fall, after the grain and corn crops have been harvested. The sheep will clean up such fields, eating the grass along the fence rows and the weeds and waste forage that was not gathered in harvesting. This will utilize feeds which would otherwise be wasted and will materially reduce the cost of maintaining the flock. It is wisest to use such feed as early as possible, before the fall rains and frosts have lessened the

value of the feed, and to leave bluegrass, clover, or timothy pasture for later use. When pasturage is deficient in the fall or the grass soft and washy, it is well to provide supplemental feed before the ewes are taken off pasture. This may be hay, grain, or better, such grazing crops as rape or fall rye.

For the greatest economy the winter feed of the ewes should consist largely of roughages, hay from the legumes easily leading. (857) Indeed, when the ewes go into the winter in good condition and are fed plenty of choice legume hay along with an allowance of roots or silage, no grain is needed until 4 to 6 weeks before lambing time. The aim should be to bring the ewes to lambing in medium flesh and vigorous condition, thus insuring a good milk flow for the new-born lambs. The trained shepherd knows that the only safe way to determine the condition of a sheep is by "handling" its back. If he finds that the ewes are not thriving, he will add concentrates to their ration. With an ample supply of good roughage, not over 0.5 lb. a head daily of concentrates is needed. While breeding ewes should not be fat, they should carry more flesh than most American farmers think proper. To winter them on only straw, or straw and hay, is to perpetuate a flock that will gradually but surely deteriorate.

Both ram and ewe lambs intended for the breeding flock should receive liberal rations of muscle-building foods during the first winter to insure steady growth, but they should never receive a fattening ration. Within the limits set by heredity, the size and vigor lambs will attain when mature depend very largely upon the development the first year.

883. Concentrates for ewes.—Not only the amount of concentrates required for breeding ewes but also the kind which should be supplied will depend upon the sort of roughages fed. When the ewes are fed plenty of good legume hay, which is rich in protein and lime, they will need less concentrates than when inferior roughage is used. Moreover, the concentrates fed may then be chiefly or entirely the farm grown grains, such as oats, corn, barley, kafir, or milo.

Whole oats are highly esteemed as a feed for ewes, while corn is considered too fattening by many shepherds to be used as the chief concentrate. However, when plenty of protein is furnished by legume hay or other protein-rich feeds and the ewes are not over-fed on corn so that they become unduly fat, corn is a satisfactory feed.

For example, in a trial at the Wisconsin Station[4] by Carlyle and Kleinheinz with ewes chiefly of the mutton breeds and ranging from 138 to 157 lbs. in weight, whole oats, wheat bran, shelled corn, or dried brewers' grains were compared, when fed as the only concentrate. Each ewe received half a pound of concentrates daily with 2 lbs. of clover and timothy hay and 2.5 lbs. corn silage. All rations proved satisfactory, these large ewes gaining steadily on half a pound of concentrates. The results from a fifth lot, fed a mixture of corn, bran, and oats, were not

[4]Wis. Rpt. 1903.

EXERCISE IS ESSENTIAL FOR THE EWE FLOCK

If the ewes do not secure plenty of exercise, they are apt to have weak lambs. In winter the ewes may be forced to exercise by scattering roughage over a nearby field. (From Wisconsin Station.)

MEAL TIME FOR THE LAMBS

Note the lamb creep in the foreground at the right, thru which the lambs have access to the grain trough, while the ewes are kept out.

A Band of Western Lambs Fattening in the Corn-Belt

Many corn-belt farmers make a practice of fattening one or more carloads of western lambs in the fall on aftermath, stubblefields, or standing corn.

Angora Goats Clearing Land of Brush

Goats are especially fond of the leaves and twigs of brush, and if pastured closely enough, will effectively kill the brush.

superior to the more simple rations. When plenty of legume hay is not fed to balance the ration, it is important that protein-rich feeds, like wheat bran, linseed meal, field peas, or cottonseed meal, be used to balance the ration. When suckling their lambs, ewes need a more abundant supply of protein-rich feeds than previous to lambing.

Linseed meal and wheat bran are important feeds for breeding ewes, as they ward off constipation, which is responsible for many of the winter troubles of the breeding flock. For this purpose 1 or 2 tablespoonfuls of linseed meal a day should suffice. A trial by Russell at the Oklahoma Station[5] shows that feeding as much as half a pound of cottonseed meal daily a head to ewes in winter may produce poisonous effects, tho one-quarter pound gave good results.

Concentrate mixtures such as the following are very satisfactory for pregnant ewes: (1) Shelled corn 5 parts, oats 3 parts, wheat bran 2 parts, linseed meal 1 part;[6] (2) corn 4 parts, linseed meal 1 part;[7] (3) oats 1.5 parts, wheat bran 1 part.[8]

884. Roughages and succulent feeds for ewes.—As has been pointed out previously, legume hay is highly important in feeding breeding sheep in winter. Not only is it rich in protein and lime, but it is also laxative. Moreover, it is usually more economical to supply the necessary protein for the ewes by feeding legume hay than thru purchasing considerable amounts of protein-rich concentrates. Alfalfa, red and alsike clover, cowpeas, vetch, soybeans, and a mixture of oats and peas, all furnish good hay for ewes. Fine-stemmed, leafy hay is relished much better by sheep than that which is coarse. Well-preserved pea or bean straw is a fair substitute for legume hay.

Timothy hay and marsh hay are unsatisfactory, for not only are they unpalatable to sheep, but also they may cause serious constipation. Moreover, the heads of timothy work into the wool, irritating the skin and lowering the quality of the wool. Bright corn fodder or corn stover, cut while the leaves are still green, is much preferable, and good bluegrass hay, oat hay, or even bright oat straw may often be used as part of the roughage. Straw alone, however, is decidedly unsatisfactory as the roughage for ewes. When no legume hay is fed, it will be necessary to feed more concentrates, and these should furnish plenty of protein. When legume hay is fed as a considerable part of the roughage, the ration will furnish plenty of lime, but otherwise there may be a deficiency, unless other feeds in the ration are high in this mineral nutrient. If lime is lacking, it should be furnished in such forms as finely ground limestone or bone meal. (**98-9, 838**)

Where some low-grade roughage must be fed to the ewes, it is best, as Coffey points out,[9] to make use of the poorer roughages before lamb-

[5]Okla. Bul. 125.
[6]Severson, Penn. Bul. 144.
[7]Hammond, Ohio Bul. 270.
[8]Kleinheinz, Sheep Management, Breeds, and Judging, p. 33.
[9]Productive Sheep Husbandry, p. 238.

ing time rather than after, because, owing to the many demands made upon them, ewes with lambs should have nutritious, easily digested feeds.

Succulent feeds aid greatly in keeping the ewes thrifty in winter when no green feed is available. Chopped roots are highly esteemed in England, Canada, and the northern United States as succulent feed for ewes, but it has been proven beyond doubt that good silage, free from mold and low in acid, is equally satisfactory and in most sections of the United States, less expensive. It is not wise to supply too much succulent feed to pregnant ewes, for shepherds declare that it produces soft, flabby lambs. Tho larger allowances are sometimes successfully used when silage of excellent quality, high in dry matter, is fed, it is usually best not to feed more than 2 or perhaps 3 lbs. of silage per head daily to ewes weighing about 150 lbs. While larger allowances of roots are often fed in England, most shepherds in this country feed no greater allowances of roots than they would of silage. Silage or roots should never be fed without plenty of dry roughage in addition.

885. Cost of maintaining ewes.—The most extensive investigations on the cost of maintaining breeding ewes have been those carried on at the Pennsylvania Station[10] by Severson and others. In these studies lots of pure-bred Shropshire and Delaine-Merino ewes were fed on various rations for several years. The following table summarizes the results during the 3 years, 1913 to 1916, for the lots fed a ration of alfalfa hay, corn silage, and a small amount of concentrates, this being the most economical ration tested. The Shropshire ewes averaged 172.4 lbs. in weight and the Delaine-Merinos, 122.4 lbs.

Average costs of maintaining breeding ewes

	Shropshires	Delaine-Merinos
Average ration for winter		
Concentrates	0.22 lb.	0.27 lb.
Alfalfa hay	2.50 lbs.	2.30 lbs.
Corn silage	3.07 lbs.	2.95 lbs.
Bedding per ewe for winter	81.14 lbs.	90.03 lbs.
Manure per ewe for winter	695.68 lbs.	773.51 lbs.
Average weight of fleece	7.66 lbs.	11.13 lbs.
Average weight of lambs at weaning	59.00 lbs.	53.10 lbs.
Cost of winter feed and bedding per ewe	$4.65	$4.52
Cost of labor in winter per ewe	.56	.56
Interest on equipment per ewe	.18	.18
Credit for manure per ewe	.87	.97
Net cost of wintering per ewe	4.52	4.29
Cost of summer feed and care per ewe	1.76	1.56
Interest on value of ewe	.60	.48
Depreciation of ewe	.50	.50
Mortality risk per ewe	.22	.17
Total annual cost per ewe	$7.60	$7.00
Profit with 125 per ct. lambs raised	$1.40	$1.51

[10]Penn. Bul. 144.

In these trials the winter feeding period averaged 158 days. During the summer the ewes were alternated on 2 pastures every 2 weeks to avoid infestation with stomach worms. No grain was fed the ewes in summer, except for a few weeks prior to and during the breeding season. The concentrate mixture fed in these trials, of which 5 parts were corn, 3 parts oats, 2 parts wheat bran, and 1 part linseed meal, cost $27.40 a ton; the alfalfa hay, $15 a ton; and the corn silage $3.50 a ton. The costs of maintaining ewes will vary quite widely under conditions in different parts of the country, but these data will be helpful as a basis for estimating the probable cost at any time.

By feeding economical, well-balanced rations to the ewes and by utilizing feed that would otherwise be wasted, the cost of maintaining a flock of breeding ewes may be kept at a minimum and the profits greatly increased.

886. Lambing time.—As lambing time approaches, the shepherd had best take quarters in the sheep barn or close by, so he will be at hand to care for the ewes. This is his harvest time, and profits depend largely on skillful attention at this period. The ewes should be separated from the rest of the flock a week prior to lambing, so they can be given special attention. But little grain should now be fed, else milk fever may develop after lambing. Before lambing, all tags of long and loose wool about the rear and the udder of each ewe should be removed. It is best to place each ewe in a lambing pen, 4 to 6 feet square, shortly before lambing or soon afterwards. Where lambs come early, the pens should be kept warmer than the quarters for the rest of the flock. Here each ewe and her new-born young remain for 3 or 4 days, until they are well wonted to each other and the lambs strong enough to look out for themselves among the flock. Then they may go back to the flock or to quarters especially set apart for the ewes and lambs.

As they enter the world, lambs of the mutton breeds often need quick, intelligent attention, which is always given by the true shepherd. The mucus should be cleaned from the nostrils and mouth of any weakling. With the first fill of milk from the dam, the new-born lamb becomes comfortable, and is usually able thereafter to care for itself. A lamb unable to draw milk within a few minutes after birth should have patient assistance. The ewe must be held, and the lamb aided, all being accomplished by that kindly, sympathetic skill so characteristic of the good shepherd. A chilled, new-born lamb is best warmed by immersing all but the head in water as hot as the hand can bear. When well warmed, it should be wiped dry, taken to its mother, and held until supplied with her milk. Some advise wrapping it in thick woolen cloths that have been warmed on a stove, and renewing these as often as they become cool. A lamb born almost lifeless may often be restored by alternately blowing gently into the mouth to start breathing, and laying it on its belly and slapping the body smartly on each side of the heart. One twin is usually weaker than the other, and frequently the

mother cares only for the stronger one. In such cases the weakling should be helped to its full share of food.

A ewe that refuses her lamb will usually accept it if they are placed together in a small pen out of sight of the other sheep and the lamb helped to suckle a few times. The stubborn ewe may be confined in stanchions so that she cannot prevent the lamb sucking. In case a ewe loses her lamb, she may often be induced to adopt a twin by first sprinkling some of her own milk over it. Still more effective is tying the skin from the dead lamb upon the back of the one to be adopted.

887. Breeding studies; weight of lambs.—The following table gives the average birth weight and percentage of increase (the annual number of lambs per 100 ewes) of lambs from ewes of different breeds, as recorded during 24 years by Kleinheinz[11] with the flock at the Wisconsin Station

Annual increase from ewes and birth weight of lambs

Breed	No. of ewes	Increase	Birth wt. of singles	Birth wt. of twins (each)	Birth wt. of triplets (each)
		Per ct.	Lbs.	Lbs.	Lbs.
Southdown	181	154	9.15	7.70	5.50
Shropshire	448	167	9.51	7.67	6.49
Hampshire	96	156	10.61	8.23	7.10
Cheviot	81	147	9.45	7.67	8.20
Dorset	30	163	10.20	8.46	7.50
Oxford	12	183	10.42	8.18	7.12

Tho there was a considerable range in the increase for the several breeds, data from many flocks covering a much larger number of animals would be necessary to show definitely any real difference in this regard. These data are of interest in showing the actual increase obtained with good feed and excellent care. The single lambs averaged somewhat heavier than the twins, and the twins larger than the triplets, tho the difference is not great.

The percentage of increase was highest with ewes 4 to 6 years old, due somewhat to discarding the poorer breeders as 3-year-olds. After the 6th year the fecundity of the ewes lessened. The larger the ewe of a given breed the greater was the percentage of increase and the larger the lambs. To a less degree the size of the ram had the same influence.

The gestation period tended to be slightly longer with large lambs. The average birth weight of the ram lambs was about 0.5 lb. greater than of ewe lambs. Of 1,804 lambs yeaned, 900 were ewes and 904 rams. As the records grow, the more nearly do the sexes balance.

888. After lambing.—Soon after lambing, the ewe should be given water with the chill removed, but should not be allowed to drink too much at a time. For 2 or 3 days but little grain should be fed, to avoid udder troubles, but she may have all the dry roughage she wishes. Close

[11]Wis. Rpts. 1902, 1907, and information to the authors.

attention must be given for a few days to see that the lamb is taking milk from both sides of the udder. All surplus milk should be drawn, or better, a needy lamb helped to an extra meal. Caked udders and sore teats should receive prompt treatment.

With the demand for more milk by the lamb, it pays to increase the ewe's ration, for lambs make the most economical gains when suckling. (114) If there is not sufficient roughage of high quality for the entire winter, the most palatable portion should be reserved until after the lambing period. Legume hay and succulent feeds are essential at this time, and more succulence can be safely fed than before lambing. An allowance of 1 lb. of concentrates a head daily, or slightly more in some cases, should be enough, with satisfactory roughage, to produce a good flow of milk.

889. Ewe's milk.—In America the milk of sheep is seldom used by man, but abroad, and especially in the mountain regions of continental Europe, it is extensively employed, both for direct consumption and for the manufacture of cheese. The average composition of ewe's milk, compared with cow's milk, has already been given in Chapter V. (115) It is there shown that ewe's milk is much richer in protein (casein and albumin) and fat, and higher in ash than cow's milk. Ewe's milk has a peculiar, somewhat unpleasant odor and taste, is thicker, and sours more slowly than cow's milk. The fat content is extremely variable, ranging from 2 to 12 per ct. The butter is pale yellow, less firm than cow's butter, and becomes rancid much quicker.

The yield of milk by sheep will vary greatly, according to breed and feed. The East Friesian milk sheep in Germany at 2 to 3 years of age yield from 3 to 4 quarts of milk daily for 2 months after weaning their lambs, and keep up an excellent flow during the autumn months. These sheep are prolific, dropping 2, 3, and even 4 lambs, individuals lambing twice a year. Three sheep are estimated to consume as much feed as 1 cow. Ordinary sheep yield from 100 to 150 lbs. of milk per year, while the milk breeds produce from 300 to 1,400 lbs.

890. Milking qualities of ewes of various breeds.—But relatively few data are available concerning the composition and yield of milk of the various breeds of sheep. In studies at the Wisconsin Station[12] by Carlyle, Fuller, and Kleinheinz, lambs were kept from their dams except at regular intervals when they were allowed to suckle. The milk yielded by the ewes was determined by weighing the lambs immediately before and after placing them with their dams. Similar studies were carried on by Ritzman at the New Hampshire Station[13] and by Neidig and Iddings at the Idaho Station.[14] The fat content of the milk of ewes of various breeds, as determined in these studies, is shown in the table on the next page.

[12] Wis. Rpt. 1904.

[13] Jour. Agr. Res., 8, 1917, pp. 29-36; N. H. Tech. Bul. 14.

[14] Jour. Agr. Res., 17, 1919, pp. 19-32.

Average percentage of fat in milk of ewes of various breeds

	Cotswold Per ct.	Dorset Per ct.	Hampshire Per ct.	Lincoln Per ct.	Merino Per ct.	Oxford Per ct.	Rambouillet Per ct.	Shropshire Per ct.	Southdown Per ct.
Wis.	...	7.2	...	...	6.0	7.7	...	5.9	8.4
N. H.	...	6.0	4.7	...	...	...	6.0	6.8	7.6
Idaho	7.7	...	7.1	8.1	...	...	7.8	8.1	7.5

There was a much greater range in the fat content of the milk of ewes of the same breed than difference between the average composition of milk for the various breeds. For example, the fat content of the milk from the Dorset ewes in the New Hampshire studies ranged from 3.8 to 12.1 per ct. The daily yield of milk in these studies ranged from less than 2 lbs. to 7.5 lbs. The available data are yet too meager to draw any definite conclusions concerning the relative milk yield of the various breeds. Ritzman found that the gains of the lambs depended not on the fat content of the milk of their dams, but upon the amount of milk yielded, a conclusion corroborated by other data. In building up a profitable flock it is therefore important to select ewes on the basis of milk production and nursing qualities, as well as on type and conformation.

891. Feed for 100 lbs. of ewe's milk.—At the Wisconsin Station Shepperd[15] recorded the milk yield of ewes receiving a mixture of 3 parts wheat bran and 1 of linseed meal, with fair-quality clover hay and sliced potatoes for roughage. Averaging together the data for 5 ewes, for 100 lbs. of milk, there were required 63 lbs. concentrates, 60 lbs. clover hay, and 34 lbs. potatoes, containing in all 113 lbs. of dry matter. When we compare these figures with those showing the amount of dry matter required by cows for 100 lbs. of milk (**540**), and further consider that the milk of the ewe is richer and that she is at the same time growing a fleece, it is apparent that good ewes are economical producers. Shepperd found that lambs consumed 640 lbs. of their dams' milk for each 100 lbs. they gained.

892. Orphan lambs.—If possible, a foster mother should be found for any orphan lamb. However, in case this can not be done, the orphan can be successfully raised on cow's milk,[16] tho close attention is necessary the first month. For the first week the lamb should have some ewe's milk, if possible, by letting it nurse ewes whose lambs are not yet old enough to take all of the milk. The cow's milk should be from a cow giving milk rich in fat, as ewe's milk is high in fat, or cream may be added. For the first 3 or 4 weeks the lamb should be given milk from the same cow. During the first few days and nights the lamb must be fed only a small amount of milk (not over 2 to 3 tablespoonfuls) at a time, but it must be fed often. For the first day it is necessary to feed

[15] Agr. Science, VI, p. 397.

[16] Coffey, Productive Sheep Husbandry, p. 262; Kleinheinz, Sheep Management, Breeds, and Judging, p. 71.

it at least every 2 hours. The milk should be fed from a bottle with a medium-sized swan-bill nipple attached and should always be warmed to approximately 100° F. by immersing the bottle in water of this temperature or slightly above. The bottle and nipple should always be carefully washed after each feeding. After the lamb is 2 to 3 weeks old, it is not necessary to feed it more than 3 times a day. Cow's milk may also be used to supply additional feed to lambs where a ewe with a scanty milk supply has twins.

893. Relative economy of lambs and pigs.—To determine the relative economy of gains by lambs and pigs, the senior author raised 4 cross-bred Shropshire-Merino lambs at the Wisconsin Station[17] on whole cow's milk and later skim milk, ground oats, and green clover. During the latter period these lambs required 830 lbs. skim milk, 119 lbs. oats, and 262 lbs. green clover for 100 lbs. gain. In all, about 204 lbs. total digestible nutrients were consumed per 100 lbs. gain. By comparing these data with the requirements for growing pigs, as given in Article **913**, it will be seen that these lambs made as economical gains as do pigs of the same age.

894. The young lamb.—When about 10 to 16 days old, the lusty young lamb will be found nibbling forage at the feed trough beside its dam, and the shepherd should provide specially for its wants, so as to accustom it early to take additional food. This is best accomplished by having an enclosure or room, called the "lamb-creep," adjoining the ewe-pen, into which the lambs find their way, while the mothers are prevented from entering because of the small size of the openings. In this space, accessible to the lambs only, should be placed a low, flat-bottomed trough, with an obstruction lengthwise over the top to prevent the lambs from jumping into it. In the trough should be sprinkled a little of some well-liked mixture of concentrates. At first the lambs will take but little, but soon they will visit the trough regularly. There should be no more feed in the trough at any time than will be quickly consumed, and any left over must be removed and the trough thoroly cleaned before the next allowance is given. Such a concentrate mixture as the following is good for young lambs: Ground corn 2 parts, crushed or ground oats 2 parts, linseed meal 1 part, and wheat bran 1 part.[18] If the lambs are all to be fattened for market, most of the concentrates may consist of corn or other carbonaceous feeds. For instance, a mixture of 5 parts ground corn and 1 part linseed meal may be fed.[19] However, corn should not form over half the concentrates for lambs to be retained for the breeding flock. After the lambs are 5 to 6 weeks old, there is no advantage in grinding the grain. (**833**)

Fine alfalfa or second-crop clover hay should also be provided, and roots, cabbage, or good silage will be appreciated. All feed should be fresh—that which is left over can be given to the pigs. Lambs will

[17]Wis. Rpt. 1890.

[18]Coffey, Productive Sheep Husbandry, p. 271.

[19]Penn. Exten. Cir. 49.

drink a good deal of water, and this also must be fresh and clean. Ram lambs not intended for breeding should be castrated when 1 to 2 weeks old, and all lambs should be docked. Some advise docking the ewe lambs when 8 to 14 days old and the rams 5 to 7 days after castration; others recommend docking at the same time the ram lambs are castrated.

895. Turning to pasture.—With the beginning of the grazing season, ewes and lambs should be turned to pasture for a short time during the warm part of the day. It is best to accomplish the change gradually and while the grass is short. After a few hours spent in the sunshine, nibbling at the grass, the ewes and lambs should be returned to shelter, where a full feed awaits them. When the grass has become ample and nutritious, stable feeding may be discontinued for ewes, or both ewes and lambs, according to the plan followed. With good pasture, breeding ewes need no grain.

It is usually best to feed lambs concentrates before weaning in addition to the food they get from their dams and the pasture. To this end, at some convenient point in the pasture let there be a "lamb-creep," and in a space accessible by way of the creep, a trough for feeding grain. Whenever the lamb passes thru the creep it should find something in this trough to tempt the appetite—oats, bran, and corn meal forming the chief feeds. A large proportion of corn may cause lambs to go off feed or founder in hot weather. Shade should always be provided for sheep and lambs on pasture.

896. Weaning time and after weaning.—Lambs of the mutton breeds, more or less helpless at birth, are lusty at 4 months of age, and will be found grazing regularly beside their dams in pasture when not at rest or eating grain within the lamb-creep. At this time they should generally be weaned, for their own good as well as to allow their dams a rest before another breeding season. If possible, advantage should be taken of a cool spell in summer to wean the lambs, as they will then be more comfortable during this trying period. The lambs should be so far separated from their dams that neither can hear the bleating of the other. For a few days the ewes should be held on short pasture or kept on dry feed in the yard. The udders must be examined, and if necessary, as is often the case with the best mothers, they should be drained of milk a few times, lest inflammation arise. The lambs should be put on some choice pasture which has been especially provided for this time and be given a liberal supply of grain in addition. It is not necessary to wean lambs of the mutton breeds before they go to market if they have been well fed, for they will reach the desired finish and a weight of 65 to 80 lbs. while suckling.

It is especially important to provide fresh pasture, free from parasites, for the lambs after weaning. If the lambs are taken from their mothers and left on a bluegrass pasture which is infested with parasites dropped by the older sheep and where the feed is scant due to heat

and drought, profitable gains cannot be expected. This practice is the chief cause of the large number of thin, scrawny lambs which reach the central live stock markets each year. The various pasture crops which are suitable for lambs are discussed in the preceding chapter. (872-6)

Lambs that are to be marketed at weaning time should be fed concentrates in addition to good pasture. It was shown many years ago in tests by Craig at the Wisconsin Station[20] that feeding the lambs suitable concentrates before weaning in addition to their mother's milk was a more economical method of preparing them for market than attempting to force them along by feeding the ewes with great liberality during the suckling period. Whether to feed grain after weaning time to lambs will depend on the relative prices of grain and pasture, and on the premium paid for well-finished lambs. From trials at the Ohio Station[21] Hammond concludes that while grain may be profitably fed to lambs on pasture, the feeding of grain after weaning is not necessary for the economical production of well-finished lambs, if an abundance of good pasture is provided. Ewe lambs to be retained in the flock need no grain when grazing is good. Ram lambs require grain during the fall to secure proper development, whether they are to be sold as lambs or retained till yearlings.

897. The stomach worm.—In the humid districts of the United States the stomach worm, *Haemonchus contortus,* is a serious menace to sheep raising, lambs being especially susceptible to attack. The eggs of the parasite pass in the droppings of the sheep and are scattered about the pastures, where they soon hatch. Sheep become infested only by swallowing the worms while grazing. Fields on which no sheep, cattle, or goats have grazed for a year, and those that have been freshly plowed and cultivated since sheep grazed thereon, are practically free from infestation. Old bluegrass pastures are especially to be avoided. It is also dangerous to allow sheep to drink from stagnant pools. During warm weather, otherwise clean pastures may become infested in from 3 to 14 days by grazing sheep thereon.

To remove the worms from the intestinal tract of sheep, various drenches are recommended, that of the United States Department of Agriculture[22] being a 1 per ct. solution of copper sulphate in water. The dose is 100 mils. (cubic centimeters), or about 3 ounces, for yearlings and older sheep, and half as much for lambs 3 months old or older. As copper sulphate is poisonous, the solution must be made up carefully and accurately administered for safety. Another drench often used is 1 tablespoonful of gasoline, thoroly mixed with 5 to 6 ounces of fresh cow's milk, with a tablespoonful of raw linseed oil added. This dose, suitable for a lamb of average size, should be increased for older sheep. The drench should be given in the morning, after the animals have been

[20]Wis. Rpts. 1896, 1903.

[21]Ohio Bul. 340.

[22]Hall, U. S. D. A. Farmers' Bul. 1150.

deprived of food and water for 16 hours. This gasoline treatment should be repeated each day for 3 days. With weak lambs the dose may be given on alternate days.

The safest plan, where sheep are infested with stomach worms, is to drench them at the beginning of the pasture season and then move them to clean pasture every 2 weeks during the summer. Annual pastures, as rape, clover seeding, etc., are well adapted to this system, for it requires several separate, clean pasture lots. Where permanent pastures are used for sheep, this plan is often difficult to follow, and it must then be modified.

The first essential is to protect the lambs, as infestation with stomach worms affects them much more seriously than older sheep. Thoroly drenching the ewes in the spring with some vermifuge will remove most of the worms and aid in keeping the lambs free from them. Immediately after weaning, the lambs should always be turned on fresh, clean pasture, on which no sheep have grazed previously that season. In a plan of rotating pastures so as to prevent serious trouble from stomach worms, advantage should be taken of the uninfested grazing furnished by stubble fields, aftermath in meadows, and corn fields. In the northern states worm-free and infested sheep may graze together from the last of September until May with but little danger. Well-fed, thrifty sheep and lambs can resist parasites much better than those getting poor feed and care.

II. Hints on Fattening Sheep

898. Fattening western lambs.—Practically none of the lambs raised on the western ranges are sufficiently well fleshed for slaughter at the end of the grazing season. Therefore they are commonly sold as feeders and then fattened for market at points where concentrates are cheaper than in the range districts. At one time most of the western lambs were fattened by large operators who each fed thousands of lambs a year. This practice, however, reached its zenith years ago, when corn and wheat screenings ruled low in price, and the large operator had little competition from the ranchman and farmer in finishing range lambs for the market. Now conditions have changed. With the increases in the prices of feed, of labor, and of feeder lambs from the ranges, the fattening of western lambs has passed chiefly into the hands of farmers who each fatten one or more carloads. Most fortunately for a conservative agriculture, the large operator, who often received no benefit from the great accumulation of rich manure in the feed lot, has usually been unable to compete with the farmer, who raises most of his feed and uses the manure to enrich his land. Prudent farmers rightly hold that enough fertility is returned to their land thru the feed lot to pay the entire labor cost of feeding.

In selecting lambs for feeding, one should chose those which will make economical gains and develop into prime or choice mutton lambs. They

should be thrifty, deep-bodied, broad, compact, and low-set, with broad, clean-cut heads, and smooth skin, free from wrinkles. Some men make a specialty of fattening weak, "pewee" lambs or old ewes, but such animals must be purchased cheap and fed with unusual care to make profit. The discussions which follow deal chiefly with the fattening of lambs, owing to the fact that lambs constitute about 75 per ct. of the sheep sold for slaughter. Also they deal largely with lambs from the western ranges. In general the same suggestions apply to farm-raised lambs which are not sold at weaning time, but are fattened in the fall or winter.

899. Hints on sheep feeding.—It has been previously pointed out in this chapter that regularity and quiet are of especial importance with fattening sheep. A striking example of this is given by Faville who reports that during a certain 2-week period of a feeding trial at the Wyoming Station[23] 160 lambs fed by McLay, a most experienced shepherd, made a total gain of 475 lbs. During the next 2 weeks McLay was absent. Tho his place was taken by a man who followed the "letter of the law," the lambs lost 85 lbs. in the 2 weeks, several going off feed. The next 2 weeks, after McLay had returned, the lambs gained 508 lbs.

In all cases before sheep are put on feed, they should be examined by an experienced shepherd, and if any evidence of skin disease or vermin is found, the flock should be dipped in the most thoro manner. In the West scab and in the East lice and ticks are common troubles. To attempt to fatten sheep afflicted with any of these pests, is to court disaster.

Lambs from the western ranges must be accustomed to grain and silage gradually, or scouring and other digestive troubles will result. At first the lambs may be fed as much hay or other dry roughage as they will clean up, but only a small amount of grain, 0.1 to 0.2 lb. per head daily, should be fed, and but little silage. The allowance of grain and silage should be increased gradually until in 6 to 10 weeks the lambs are on full feed. During none of this time should more grain be fed than will be cleaned up in a few minutes. In no case should getting the lambs on feed be hurried, for it means a waste of feed and injuring if not losing some of the animals. It is a good practice to start the lambs on a mixture made up chiefly of a bulky feed, like oats or wheat bran, and gradually increase the proportion of corn or other concentrated feed, until when on full feed the lambs may be given only corn with a small amount of a protein-rich supplement, if needed to balance the ration. (**845**) On warm days in winter it is often necessary to reduce the grain allowance slightly, or the lambs may go off feed.

Sheep feeders do not begin operations at an early hour in winter, preferring not to disturb the animals until after daybreak. Usually grain is first given, followed by silage if this is fed, with the hay last. The trough in which grain is fed should be kept clean at all times, and there should be ample space, so that each animal may get its share of

[23]Wyo. Bul. 89.

grain. Plenty of salt and fresh water should always be supplied fattening lambs and sheep.

900. Length of feeding period.—Usually 75 to 100 days or longer are required to produce the desired finish on western lambs, less time being needed for yearlings. During this period the lamb should gain 20 to 30 lbs. a head. This gain added to a lamb weighing originally 55 to 65 lbs. brings it to the size desired by the market. Formerly the market called for a large lamb, but now the demand is for plump ones weighing from 80 to 90 lbs., or even less if they are from the western ranges. As soon as lambs are ripe, or when the back and the region about the tail seem well covered with fat, they should be sold, for further gains cannot be made at a profit. Ripe lambs fed a heavy grain ration at the North Dakota Station[24] gained only 0.8 lb. each in 4 weeks, returning a heavy loss instead of profit.

If one is fattening more than a single carload of lambs at the same time, it is wise to sort out and market the fleshiest lambs before the others are finished. While it is important to market lambs as soon as they are finished, it is just as important not to sell them before they are sufficiently well fleshed to bring a good price, as many farmers do, perhaps owing to lack of feed.

901. Rations for fattening lambs; cost of gains.—From the many trials reviewed in the preceding chapter, the feeder can readily determine the best combination of feeds to employ under his local conditions. The tables showing the amount of feed required for 100 lbs. gain will enable him to compute the approximate cost of gains with feeds at market prices. It should be remembered that the results presented were secured with thrifty lambs, fed by skilled feeders and under good conditions. The feed required for a given gain will therefore often exceed the amount stated. Comparing the cost of gains, it will be found that lambs give better returns for the feed supplied than do steers. The gains of mature sheep will cost from 25 to 30 per ct. more than those of lambs.

902. Proportion of concentrates.—Under conditions thruout the corn belt and the eastern states, it is usually most profitable to give fattening lambs a liberal allowance of grain after they have been brought onto feed, in addition to all the good roughage they will clean up. They will then reach the desired finish and sell at a higher price than if they had been less thoroly fattened. Even with corn at the high prices of 1917 to 1919, in trials at the Indiana Station[25] by Skinner, Starr, and Vestal, giving fattening lambs a full feed of corn was more profitable than feeding a half allowance of corn, or than feeding no corn the first 50 days and then full feeding corn thereafter. Each lot was fed all the corn silage and clover hay they would clean up, and enough cottonseed meal to balance the ration. Tho the cost of gains was less in some instances where the allowance of corn was restricted, this was

[24]N. D. Bul. 28.

[25]Ind. Buls. 221, 234, and 256.

more than offset by the fact that the lambs were not so well finished and hence brought a lower price. Similar results were secured in trials by Coffey at the Illinois Station[26] in which western lambs were fed allowances of corn ranging from 0.5 lb. to 1.4 lbs. per head daily, with all the alfalfa hay they would eat. Gramlich obtained like results at the Nebraska Station.[27]

On the other hand, in the West, where hay is usually cheap compared with grain, the allowance of grain is often restricted. If the lambs are to be sold on a local market which does not pay a premium for well-finished animals this is decidedly the more profitable course to follow.[28] Since lambs can not be made fat on alfalfa hay alone, many western feeders feed hay alone during the first of the feeding period and then add grain to finish the lambs and harden the flesh.

903. Fattening lambs in the fall.—Finishing lambs for market in the fall is a common practice with farmers who raise their own lambs and many who buy western feeder lambs. Until cold weather sets in the lambs may be grazed on rape or other pasture, with or without grain in addition. Thrifty lambs placed on feed in the fall should be ready for sale in December or early in January, a season when there is usually a scarcity of good lambs on the market, since the grass-fed lambs have been marketed and those in winter feed lots are not yet finished.

In some sections train loads of lambs are annually distributed in August among the farmers of a neighborhood and by them given the run of the stubble fields from which the small grain has been harvested. Often rape has been sown on the fields to increase the herbage, the seeding not taking place until the small grain is well above ground, lest the rape grow so large as to injure the grain crop. The stubble fields well cleaned, the lambs may be finished by turning them into fields of standing corn.

904. Fattening in the corn field.—During recent years the practice of fattening lambs or sheep in the corn field has increased to a marked extent. Where it is intended to follow this practice, such supplemental crops as rape or soybeans should be grown in the corn. When turned into standing corn in the fall, at first the lambs will clean up the other vegetation, including most of the weeds. Then they will begin eating the corn leaves and finally learn how to husk out the corn ears and eat the grain from the cobs. During each of 2 autumns Gramlich full fed one lot of lambs on shelled corn and alfalfa at the Nebraska Station[29] and fattened another lot in a corn field. Both years the lambs in the corn field were fed 0.2 to 0.3 lb. linseed meal per head daily to balance the ration. All the alfalfa hay the lambs would eat was fed in addition thruout the first trial and was supplied in the second trial after severe freezing started. The lambs in the corn field gained 0.38 lb. per head daily while those fed shelled corn and alfalfa hay in the feed lot gained

[26]Ill. Bul. 167.
[27]Nebr. Bul. 170.
[28]N. Mex. Bul. 79.
[29]Nebr. Buls. 167, 170.

0.33 lb. The feed cost of 100 lbs. gain was about 15 per ct. less for the corn-field lambs. These trials show this method of fattening lambs to be a decidedly economical practice, especially in view of the saving in labor. Gramlich found that the gains were increased when a supplement, such as linseed or cottonseed meal, was given to lambs in the corn field, even tho they were receiving alfalfa hay.

In fattening sheep in the corn field, Coffey[30] points out that plenty of feed should always be easily accessible, without the animals being forced to travel a long distance. It is a good plan to furnish pasture, such as clover, bluegrass, or timothy, near the corn field, for this aids in keeping the sheep from over-feeding on corn. Hay and other feed should be provided for periods of bad weather or in case the corn field is harvested before the sheep are fat. Shelter from cold rains should be furnished. The sheep should be restricted to limited areas in the corn field by means of hurdles or temporary fences which may be fastened to the corn stalks. When most of the feed in a given area has been eaten, it is a good plan to let the pigs finish the harvesting and turn the sheep into a new portion. The sheep should be inspected daily to see that all are thriving. Muddy fields are hard on their feet, as the mud cakes between their toes.

905. Winter fattening by large operators.—Most of the large operators who still fatten thousands of lambs each year carry on their feeding in Colorado or other western states. A few feed at yards located near the large livestock markets on railroads leading in from the West. In the western states alfalfa hay is the chief roughage, with wet sugar beet pulp in the vicinity of beet sugar factories. In Colorado, corn is the chief grain fed, while farther north and west larger use is made of the small grains, especially barley.

In the West no shelter except perhaps a windbreak is commonly provided. The hay is usually fed in lanes which extend between 2 rows of lots, each of which accomodates 400 to 500 lambs. The low fences bordering the lanes have a 7- or 8-inch space between the first and second boards, thru which the lambs feed on the hay. About 1 running foot of lane fencing and feed troughs is allowed each sheep. The hay from the stacks is hauled down the lanes and piled along the fences, being pushed up to them 2 or 3 times a day as it is eaten away. The grain is fed in flat-bottomed troughs.

With favorable markets and low-priced feed, handsome profits were made by the large operators, but sometimes heavy losses occurred. In the West often little or no use is made of the manure produced, but at the feeding yards near the central markets, the manure is dried, pulverized, and sold for fertilizer. As has been mentioned in the preceding chapter (860), large numbers of lambs are fattened on field peas in certain districts of the West, particularly the San Luis Valley

[30]Ill. Exten. Cir. 21; Productive Sheep Husbandry, pp. 388-90.

in Colorado. Many are also fattened largely on pea-vine silage in the vicinity of pea canneries, especially in Wisconsin.

906. Winter fattening in the corn belt.—In the corn belt and eastward corn, clover or alfalfa hay, and usually silage in addition are commonly used for fattening lambs, with or without cottonseed meal, linseed meal, or other protein-rich supplements. Thruout these districts it is usually most profitable to feed the lambs all the grain they will eat after being brought to full feed. Feeders frequently fatten two lots of lambs the same season, marketing the first in January and the second late in spring. Should the weather grow warm before the lambs are finished, shearing results in better gains. Shelter is required to protect the lambs from winter storms. In the corn belt lambs are commonly allowed the freedom of small yards with an open shed or barn adjacent.

907. Winter fattening in the East.—In the East a more forced system of fattening is often followed, the lambs never being turned out from the barn or shed for exercise. In this system the grain troughs are protected by vertical slats in such a manner that there is just room for a lamb to feed in each opening, and only one space is provided for each lamb. The lambs are brought to full feed as quickly as possible, and they are then given all the grain they will clean up. With such heavy feeding and scant exercise, care must be taken to keep the lambs quiet, and a feeding space must be closed up whenever a lamb is removed from the pen, for excitement and overeating cause heavy losses from apoplexy.

III. Hot House and Spring Lambs; Goats

During recent years an increasing demand has developed for winter, or "hot house" lambs. The term "hot house" lambs does not mean that they are reared in artificially heated quarters, but has been applied because the lambs are produced at an unusual season and are hence comparable to the out-of-season products of hot houses. The greatest obstacles to success in this specialty are getting the ewes to breed sufficiently early, and producing carcasses which meet the exactions of the epicure. The demand for winter lambs prevails from the last of December to Easter, the price usually being the best between New Year's and the first of April. The condition of the carcasses of such lambs is more important than their size. They must be fat and present a well-developed leg of mutton with plenty of tender, juicy lean meat and a thick caul to spread over the exposed flesh of the carcass when on exhibition. Winter lambs should weigh alive from 45 to 60 lbs. Large but lean and bony ones present a staggy appearance and bring unsatisfactory prices. Early in the season small lambs top the market, but later the heavier ones are in demand.

908. Breeding for winter lambs.—The ewes best suited for winter lamb production are pure-breds or grades of the Dorset, Tunis, and Merino or Rambouillet breeds, for the other breeds can not usually be

depended on to breed sufficiently early.[31] However, Hampshires, Shropshires, and Southdowns are occasionally used with success.

At the Minnesota Station,[32] in trials covering 6 years, Shaw found that the breeding habit of common grade ewes which usually drop their lambs in the spring may be so changed by 2 or 3 generations of judicious crossing and the selection of the early yeaned lambs for breeders that they will drop lambs in fall and early winter. This change can be hastened and more permanently fixed by mating the ewes with pure-bred Dorset rams. Where the ewes have the early breeding habit well fixed, superior lambs may be obtained by using dark-faced rams, such as Shropshire and Southdown. Shaw further found that ewes which have suckled winter lambs breed more readily before being turned to grass than subsequently, especially when fed a stimulating grain ration while still in the shed. At the New York (Cornell) Station[33] Dorset ewes bred earlier, stood forced feeding better, and were less affected by unfavorable weather than Shropshire ewes, and their lambs made more rapid gains. Miller and Wing[34] advise using a young ram, well fed during service but not too fat, turning him with the ewes not earlier than the middle of March nor later than the middle of May. The ewes should be in good condition and so fed as to be gaining in flesh. Even with favorable conditions, all the ewes will not breed at the desired time, and to secure 400 winter lambs about 500 ewes are necessary. Ewes which fail to breed are sold early, and those breeding late drop lambs useful for later sales. Ewes which are successful breeders are kept as long as possible, since those lambing in November are likely to breed at the right time the following year.

909. Care of the ewe.—During the summer the ewes need abundant pasture, water, and shade. Should the grass become scant, they should receive additional feed—rape, pumpkins, etc. If in good condition, it is rarely necessary to feed grain before lambing, and then only in small amount. The ewes should be shorn in the fall or as early in winter as possible so as to keep them cool. At lambing time the ewes should be removed to the lambing pen and fed lightly for a few days. The lambing pen should be warm so that the new-born lambs will not be chilled. Alfalfa and clover hay with silage or roots serve best for roughage, while oats, bran, oil cake, and corn prove suitable concentrates. The object at all times is to produce the largest possible flow of milk to hasten the lamb's growth. In trials at the Ohio Station[35] Hammond found a mixture of 4 parts corn and 1 part linseed meal was as satisfactory for ewes raising winter lambs as one of 5 parts corn, 2 parts oats, 2 parts bran, and 1 part linseed meal, when fed with alfalfa hay and corn silage. Corn and alfalfa hay proved a good combination to feed the suckling lambs.

[31]Wing, Savage, and Tailby, N. Y. (Cornell) Bul. 309.
[32]Minn. Bul. 78.
[33]N. Y. (Cornell) Bul. 88.
[34]The Winter Lamb, p. 6.
[35]Ohio Bul. 270.

910. The lambs.—A creep should be provided and the lambs taught to eat from a trough as soon as possible. To this end, a little sugar may sometimes be sprinkled on the grain to render it specially palatable. The lambs begin to eat freely when 2 or 3 weeks old, and are forced on bran, cracked corn, linseed meal, ground oats, barley, gluten feed, etc. They should be induced not only to eat, but to eat a large quantity, and to keep eating. Alfalfa, clover, or soybean hay is indispensable, while roots and silage are helpful. The feed troughs should be cleaned each morning, and the grain and hay supply be changed 2 or 3 times a day. When necessary, lambs are fed new milk from a nursing bottle or from a teapot having a punctured rubber cot placed on the spout. Ewes bereft of their lambs thru sale are given one of a pair of twin lambs. Thus forced, the best lambs weigh from 50 to 60 lbs. alive at 10 to 12 weeks. For the eastern markets the lambs are "hog dressed"; i. e., the feet and all the viscera, except the heart, liver, and kidneys, are removed, but the pelt and frequently the head left on. The caul fat is carefully spread over the exposed parts, and the carcass sewed up in muslin after thoro cooling. This specialty can be conducted with profit only by experts who have gained their experience thru patient and discreet effort, and who have nearby markets that will pay the high prices such products must command.

911. Spring lambs.—A less intensive system than the preceding is the production of spring lambs. These should be dropped from January to March and are usually marketed in May and June, weighing 65 to 90 lbs., at a time of the year when there is a good demand for lambs. Raising spring lambs is especially profitable in Tennessee, Kentucky, Virginia, and states to the southward, for here the ewe may be largely maintained on pasture thruout the year, greatly lowering the feed bill. In the middle Tennessee basin the raising of spring lambs is an important industry.[36] The ewes are pastured in summer and allowed to run on the fields after the crops are removed. Such crops as winter rye and oats provide pasture at practically all times during the winter. The sheep receive little grain and commonly no shelter is furnished except a windbreak or trees. The profits could be materially increased by using better rams than is the practice, and by feeding the lambs more grain so as to have them well-finished when prices are high.

912. Goats.—The raising of Angora goats for their mohair has become an industry of considerable importance in certain districts of the United States, especially Texas, New Mexico, Arizona, Oregon, and California. According to the census of 1920 there were 1,753,112 goats in Texas and 226,862 head in New Mexico. In the western states the goats graze upon rough land, utilizing browse which even sheep would refuse. In the cut-over districts of the North, Angora goats are useful in clearing land of brush.

[36]Tenn. Buls. 84, 114; Willson, Breeder's Gaz., 80, 1921, p. 587.

Milk goats are of considerable importance in continental Europe, many families, especially of the poorer classes, relying on goats for their daily supply of milk. In Germany alone there were over 3,000,000 milk goats before the World War. While they have not yet become numerous in this country, milk goats are receiving increasing attention in some districts, as they are especially well suited to families living in small towns and in the suburbs of large cities. Often they can secure much of their feed by grazing in waste places, such as vacant lots and rocky hillsides. In such localities as some of the western mining towns, goats have a decided advantage over cows as they always come home at night from wherever they have been grazing.

In general the same feeds which are used for dairy cows are suitable for milk goats. From 6 to 8 goats can be kept upon the feed required for a cow. Shaw reports[37] that a ration of 2 lbs. alfalfa or clover hay, 1.5 lbs. silage or turnips, and from 1 to 2 lbs. concentrates has proven very satisfactory for the milk goats in the experimental herd maintained by the United States Department of Agriculture. On pasture 1 to 1.5 lbs. of concentrates were fed. The concentrate mixture used should be similar to those used for dairy cows. Often the use of refuse from the kitchen will considerably reduce the feed bill. At prices in 1912 to 1914 the cost of feeding a goat a year was found to be $11.05 by Jordan and Smith at the New York (Geneva) Station[38] and $11.24 by Voorhies at the California Station.[39] A good milk goat should yield 2 quarts or more of milk a day and continue in milk for 7 to 10 months. The principles of feeding and care which have been presented for sheep also apply in general to goats.

[37]U. S. D. A. Farmers' Bul. 920.
[38]N. Y. (Geneva) Bul. 429.
[39]Cal. Bul. 285.

CHAPTER XXXIII

GENERAL PROBLEMS IN SWINE HUSBANDRY

The pig excels all other farm animals in the economy with which he converts feed into edible flesh, requiring but 4 to 5 lbs. of dry matter to produce a pound of gain, while fattening cattle require from 10 to 12 lbs. The pig yields from 70 to 80 per ct. of his live weight as dressed carcass; the steer only 50 to 60 per ct. Moreover, pigs will profitably utilize many by-products of the farm often otherwise lost, such as dairy by-products and kitchen and garden waste, as well as grains that cannot otherwise be disposed of profitably. No other lines of stock farming can so quickly be brought to profitable production with limited capital invested in stock and equipment as can the making of meat from the pig. Due to this efficiency in producing human food, pigs steadily increase in importance as our population becomes more dense.

Practically every farmer should raise and fatten pigs, for family consumption if not for market, in order to save feed that would otherwise be wasted. In many cases he should not only fatten his pigs but also slaughter them and market the cured products, obtaining increased profits even tho the undertaking be a small one.

913. Rate and economy of gains by pigs.—The economy with which pigs of different weights convert feed into meat is shown in the following table, summarizing the data from over 500 feeding trials with more than 2,200 pigs at many American experiment stations. In this table 6 lbs. of skim milk or 12 lbs. of whey is rated as equal to 1 lb. of concentrates.

Relation of weight of pigs to feed consumed and rate of gain

Wt. of pigs	Actual av. wt.	No. of animals fed	Feed per head, daily	Feed eaten daily per 100 lbs. live weight	Av. gain per day	Feed for 100 lbs. gain
Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
15 to 50	38	174	2.2	6.0	0.8	293
50 to 100	78	417	3.4	4.3	0.8	400
100 to 150	128	495	4.8	3.8	1.1	437
150 to 200	174	489	5.9	3.5	1.2	482
200 to 250	226	300	6.6	2.9	1.3	498
250 to 300	271	223	7.4	2.7	1.5	511
300 to 350	320	105	7.5	2.4	1.4	535

The previous table points out several facts of great importance to the pork producer. While the amount of feed eaten per head daily increases as the pigs grow larger, the amount consumed per 100 lbs. live weight

decreases rapidly. In other words, young pigs have a greater capacity for consuming feed than older ones, per 100 lbs. live weight. The average gain per day started at 0.8 lb. for pigs weighing under 50 lbs., and gradually increased until those weighing 250 to 300 lbs. showed a daily gain of 1.5 lbs. The last column, perhaps the most important, shows that as pigs grow older, they require more and more feed for 100 lbs. gain, the gains thus constantly becoming more expensive.

The greater production from the younger pigs is due partly to the fact that they consume more feed per 100 lbs. live weight and consequently have a greater surplus from which to make gain after their bodies are maintained. Also, 100 lbs. of gain made by young pigs has less food value than the same amount made by 250-lb. pigs, for the gain of the younger pigs contains more water and less fat. (114) Due to the increased cost of the gains as they mature, most pigs are now marketed when weighing only 250 lbs. or less.

The following table shows the average results secured during 6 years with pigs self-fed corn and tankage on good pasture in trials by Morrison, Bohstedt, and Fargo at the Wisconsin Station.[1] In these trials a total of 320 pigs were fed from weights of 50 or 60 lbs. to market weights of 200 lbs. or more. The pasture crops included alfalfa, red clover, sweet clover, rape, and such mixtures as oats-peas-and-rape.

Gains of pigs of various ages on good pasture

Wt. of pigs	Actual av. wt.	Concentrates per head daily	Daily gain	Concentrates for 100 lbs. gain	
				Corn	Tankage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
50 to 75 lbs.....	64.5	3.2	0.90	333	26
75 to 100 lbs.....	88.5	4.2	1.15	340	29
100 to 150 lbs.....	127.1	5.7	1.50	363	26
150 to 200 lbs.....	175.8	6.9	1.55	443	20

This table shows about what may be expected of pigs self-fed well-balanced rations on good pasture. It will be noted that the amount of feed required for 100 lbs. gain increased in each period, but that there was no very rapid increase until the weight of 150 lbs. was reached.

To secure data on the economy of the gains made by pigs fed under uniform conditions without pasture to a weight of 500 lbs., Robison conducted 3 experiments at the Ohio Station.[2] In these trials, which are summarized in the following table, pigs were hand-fed in dry lots from birth to the end of the experiment and a careful record was kept of all feed consumed. When the pigs reached weights of 100, 200, 300, 400, and 500 lbs., respectively, certain animals were slaughtered to determine the dressing percentage at that weight. In the table the feed consumed

[1]Unpublished data compiled by McKay.

[2]Ohio Bul. 335.

for the first period includes the feed eaten by both sows and pigs up to weaning time.

This table shows the same general facts as the one on the previous page. These pigs made remarkably rapid and economical gains during the latter periods, considering the heavy weights to which they were carried, and the further fact that they were not on pasture during the trials. Such results are possible only with carefully selected animals, fed well-balanced rations under expert supervision. The last column, which gives the dressing percentage of the pigs slaughtered at the end of each period, shows that the percentage of dressed carcass to live weight increased gradually as the pigs became older and fatter. (29)

Economy of gain of pigs at different stages of growth

Wt. of pigs	No. of pigs	Feed per head daily	Feed daily per 100 lbs. live wt.	Daily gain	Feed for 100 lbs. gain	Dressing percentage*
		Lbs.	Lbs.	Lbs.	Lbs.	Per ct.
Birth to 100 lbs..	37	2.2	4.2	0.81	304	77.7
100 to 200 lbs...	30	6.1	4.0	1.70	359	83.4
200 to 300 lbs...	23	7.6	3.0	1.83	415	86.4
300 to 400 lbs...	16	7.8	2.8	1.71	470	88.1
400 to 500 lbs...	7	8.0	1.6	1.58	510	88.2

*Average for 2 experiments.

In these trials the pigs returned a greater margin over the cost of feed for each 100 lbs. of pork produced when marketed at about 200 lbs. live weight than at weights of 300, 400, or 500 lbs. This shows that ordinarily one should raise enough pigs to dispose of the available feed by the time they reach the usual market weights of 200 to 250 lbs. If the number of pigs is limited compared with the amount of feed which one desires to market thru them, and if the price of pork is high compared with the price of grain, then it may be most profitable to carry the pigs to heavy weights. Under such conditions this would bring the largest *total profit*, tho the *profit per 100 lbs. of pork produced* would be lower.

914. Nutrient requirements of swine.—Swine are fed largely on grain, and they eat relatively little roughage, except when on pasture. Moreover, they grow more rapidly than cattle, horses, or sheep, and produce young when less mature. Due to these facts, swine suffer much more frequently than other classes of live stock from inadequate rations. It is therefore especially necessary, if maximum profits are to be secured from pork production, that their nutrient requirements be clearly understood. In no field of animal husbandry have the recent discoveries in stock feeding had a more important bearing than upon practical pork production. These experiments show that the nutrient requirements of swine are relatively simple, when once understood, and that it is not necessary to feed complicated or expensive rations in order to secure the best results.

915. Protein requirements of swine.—Since pigs grow rapidly, they need an abundant supply of protein in their rations, to furnish the building material for the rapidly developing muscular tissues and the internal organs as well. Furthermore, the supply of protein must not only be ample in *amount,* but also the proteins must be of the right *quality.* This last requirement is of much greater importance in the feeding of swine than with cattle, horses, or sheep. This is because swine are commonly fed chiefly on the cereal grains, and the proteins of all grains are unbalanced in composition, being low in certain of the necessary amino acids. Moreover, many of our common protein-rich swine feeds do not balance the proteins of the cereals efficiently. For example, grain with only wheat middlings, linseed meal, gluten feed, or corn germ meal, makes a very unsatisfactory ration for young pigs not on pasture. (**118, 938**) This is probably due primarily to the unbalanced nature of the proteins such rations furnish, tho these supplements are also low in calcium. (**98, 119**) On the other hand, skim milk, buttermilk, whey, tankage, and fish meal, all of which are animal products, supplement the cereals in a most efficient manner, for they supply proteins which are rich in the very amino acids deficient in the grains.

Fortunately for economy in pork production, all good pasture crops, such as alfalfa, clover, and rape, are not only rich in proteins and in calcium, but their proteins are quite high in those amino acids which are low in the grains. Therefore, pigs on good pasture make quite good gains on corn supplemented by only linseed meal, wheat middlings, or corn germ meal. (**969, 973**)

Legume hay has an important place in swine feeding, due to its richness in protein and calcium, and also because the proteins are quite well balanced. (**1009**) The high value of alfalfa hay and hay from other legumes for brood sows in winter is emphasized later. (**1016**)

Pigs can not be expected to consume much dry roughage, owing to the nature of their digestive tracts. However, even for them legume hay is often an exceedingly important feed. For example, if pigs not on pasture must be fed grain supplemented by such feeds as linseed meal or wheat middlings, without any feed of animal origin, better gains will be secured if a little legume hay is added to the ration. Also, even such a good ration as corn and tankage is improved by adding a little alfalfa hay to it, or still better, both alfalfa hay and linseed meal. (**1010**) For fattening pigs, ordinarily not over 3 to 5 per ct. of the feed should be hay, or the ration will be so bulky that the gains will be lessened.

916. Mineral requirements.—Swine suffer much more commonly than horses, cattle, or sheep from a lack of calcium in their rations. This is because they are fed largely upon the cereals, and also on account of the rapidity of their growth and the confinement under which they are often reared. It is well known that frequently pigs become crippled during growth or on shipment to market, and brood sows often break down while suckling their pigs. These troubles may be due, in part, at

least, to a lack of minerals in their rations. It has been pointed out previously that common salt should always be supplied to swine, as well as to horses, cattle, and sheep, and that calcium is the mineral nutrient which is most apt to be lacking, in addition to common salt. (**95-100**) Phosphorus may be deficient in amount if unbalanced rations, low in protein, are fed. If the ration contains plenty of protein, the supply of phosphorus will usually be ample for good results, because most protein-rich feeds are high in phosphorus. In some sections it may also be necessary to add iodine to the ration to prevent hairless pigs. (**917**)

Tho pigs require less salt than the other farm animals, they should be supplied with it regularly. In a trial by Evvard at the Iowa Station[3] pigs allowed free access to salt made better gains than those receiving no salt or others getting allowances of one sixty-fourth, one thirty-second, or one-sixteenth ounce per head daily. Salt may be supplied in a trough or a small self-feeder. If pigs have not had free access to salt they may at first overeat if allowed free access to it. (**100**)

If pigs are fed well-balanced rations on such pastures as alfalfa, clover, or rape, good results will be secured without the addition of any mineral supplement except common salt. Indeed, if plenty of skim milk, buttermilk, tankage, or fish meal is fed to balance the ration, there is no definite proof that there is any advantage whatsoever in adding a mineral supplement to furnish additional calcium or phosphorus where swine are on good pasture. Likewise if brood sows are fed well-balanced rations in winter, including legume hay and also a protein-rich feed of animal origin, such as skim milk or tankage, there is no conclusive evidence that there is any benefit from adding supplements to furnish more calcium or phosphorus.

Where less ideal rations than these are fed either to pigs or to brood sows, there may be an advantage in adding mineral supplements supplying calcium, and perhaps phosphorus also. For example, in a trial by Evvard at the Iowa Station[4] pigs fed corn and a mixture of 40 parts of linseed meal, 40 parts of corn germ meal, and only 20 parts of tankage made slightly more rapid and economical gains when such mineral supplements as ground limestone or spent bone black were supplied in addition. One of the primary reasons why forage crops are so indispensable in pork production is that they are, in general, rich in mineral matter, especially lime, in addition to being rich in protein of good quality. In view of the limited amount of data on the mineral requirements of swine at present, it is probably wise to supply a simple and cheap mineral mixture for all swine not on pasture, except perhaps when they are fed excellent well-balanced rations, including calcium-rich feeds of animal origin, such as skim milk or tankage, and also legume hay.

Many different mineral mixtures have been suggested by various authorities, and several proprietary mixtures are being advertised extensively by commercial concerns at the present time. Some of these pro-

[3]Information to the authors.

[4]Information to the authors.

prietary preparations sell for extravagant prices, considering the actual cost of the ingredients of which they are composed. Also exaggerated and even entirely false claims have in some instances been made in advertising such mixtures. Any farmer can provide at small expense a simple home-prepared mineral mixture which, so far as is known, will be just as effective as the best proprietary mixtures, and will certainly give better results than some of those on the market.

From the preceding discussions it is clear that the mineral nutrient which, in addition to common salt, is most apt to be lacking in the rations of swine is calcium and next to this comes phosphorus. Calcium can be supplied very cheaply indeed by using finely ground limestone, air-slacked lime, chalk, or wood ashes. When there is a possibility of phosphorus being lacking as well as calcium, it is best to supply both these minerals in such forms as steamed bone meal, spent bone black, or even ground rock phosphate, tho experiments by Forbes and colleagues at the Ohio Station[5] show that the latter is not utilized as well as are bone products. Other ingredients are also often incorporated in mineral mixtures, especially charcoal, sulfur, Glauber's salts (sodium sulfate), Epsom salts (magnesium sulfate), and copperas (iron sulfate). While some of these ingredients may perhaps be useful as tonics or correctives for animals which are "off feed" or in poor condition, there is no positive evidence to show that there is any benefit from giving them to an animal which is thrifty and making normal gains.

If one is feeding ground grains or other ground concentrates, the mineral supplement may be mixed directly with the concentrates. There will then be no question but that the pigs will eat the desired amount. One-half to one pound of any of the calcium-rich mineral supplements previously mentioned to each 100 lbs. of concentrates should ordinarily be an ample amount for pigs or brood sows.

When shelled corn or ear corn is fed, the mineral supplement can not be mixed with the feed, but should be fed separately in a suitable box or self-feeder. Such mineral supplements as ground limestone, wood ashes, ground rock phosphate, and bone meal are not very palatable to pigs, and hence they may not eat enough of the supplement to have the desired effect. To increase the palatability of the mineral supplements, salt may be mixed with them. Forbes has found recently at the Ohio Experiment Station[6] that "the one unrivalled perfume and appetizer" for mixing with such supplements is tankage or meat meal. Accordingly he advises that one pound of tankage be added to each nine pounds of mineral supplement when it is not to be mixed with the feed.

There are insufficient data available to show definitely whether a complex mineral mixture including several of the ingredients previously mentioned will produce any better results than merely such simple combinations as the following:

[5] Ohio Bul. 347.
[6] Ohio Mo. Bul. 55.

WHITE CORN LACKS FAT-SOLUBLE VITAMINES

Above.—Pigs fed yellow corn and skim milk from weight of 65 lbs. These pigs, fed at the Wisconsin Station, are all thrifty and have made good gains. See Pages 606 and 626-7.

Below.—Pigs fed white corn and skim milk. Four of the pigs in this lot succumbed, because of the lack of fat-soluble vitamines in this ration. Two of them are shown in the plate facing Page 76. The pigs which lived made unsatisfactory gains.

LEGUME HAY MAKES GOOD THE DEFICIENCY OF WHITE CORN

Above.—Pigs fed mixture of 95 per ct. yellow corn and 5 per ct. alfalfa hay with skim milk. Average daily gain, 1.1 lbs.

Below.—Pigs fed mixture of 95 per ct. white corn and 5 per ct alfalfa hay with skim milk. This small amount of alfalfa hay has saved the pigs from disaster. All are thrifty and have made as good gains as those fed yellow corn.

THE SCOOP SHOVEL METHOD OF PREPARING CORN FOR PIGS

For pigs under 150 lbs. in weight, shelling or grinding corn does not increase its value. For older pigs the saving by grinding is only 6 to 7 per ct. (From Iowa Station.)

SELF-FEEDING IS AN ECONOMICAL METHOD OF FATTENING PIGS

This labor-saving method of feeding gives excellent results with growing, fattening pigs, with well-grown shotes, and with old sows which are being fattened. (From Wisconsin Station.)

(1) Equal parts by weight of ground limestone and salt; or equal parts wood ashes and salt. These supply calcium but no appreciable amounts of phosphorus.

(2) Equal parts of ground limestone, salt, and either bone meal or ground rock phosphate. This furnishes both calcium and phosphorus.

(3) Nine parts of either bone meal or ground rock phosphate and one part tankage for flavoring. These mixtures also furnish both calcium and phosphorus.

If one desires to use a more complicated mixture than these, he might use the following, which was suggested by Evvard.[7] He, himself, however, states that after comparisons of simple mineral mixtures with more complex combinations, he is inclined to leave out such ingredients as copperas and Epsom salts, until such time as they have been proved to be useful:

Salt, common, flake form	30.0 lbs.
Spent bone black, or bone meal, finely ground, or bone flour	25.0 lbs.
Commercial kainit, or potassium chloride, or wood ashes	12.0 lbs.
Sulfur, flowers of	10.0 lbs.
Air-slaked lime, or limestone, finely ground	10.0 lbs.
Glauber's salts or sodium sulfate	5.7 lbs.
Epsom salts or magnesium sulfate	5.0 lbs.
Copperas, or iron sulfate	2.0 lbs.
Potassium iodide	0.3 lb.
Total	100.0 lbs.

As yet, it is impossible to state definitely just what mineral mixtures will give the best results. However, this matter is now being investigated at several different experiment stations, and soon there should be much further knowledge gained on this important question.

917. Hairless pigs.—In some sections, especially in certain districts of the Northwest, heavy losses have been experienced in recent years from "hairlessness" or goitre in new born pigs. Pigs so affected are practically hairless or have very light coats of hair at birth, and have large necks and thick pulpy skin. In severe cases, if the pigs are born alive, they are generally so weak that they live but a few hours. It has been pointed out previously that this trouble is due to the thyroid gland in the neck being diseased and enlarged, just as in the case of humans suffering from ordinary goitre. This is apparently brought about by a lack of iodine in the feed or a failure of the body to absorb and use the traces of iodine usually present in the feed. As has been shown elsewhere, the disease may be prevented or cured by administering iodine in the form of potassium iodide to the sows while they are pregnant. (**101**)

Hairless pigs are most apt to be produced in spring after a severe winter with a heavy snowfall, when the sows do not take much exercise. In most districts goitre or hairlessness is rare if brood sows are fed well-balanced rations, neither too low nor too rich in protein, and if they get plenty of legume hay and secure ample exercise. Therefore it is usually

[7] Iowa Cir. 70.

not advisable, except perhaps with very valuable brood sows, to go to the expense of the iodine treatment unless there has actually been previous trouble from the disease.

Experiments at the Montana, Washington, and Wisconsin Stations[8] show that hairless pigs can be prevented by giving iodine to the sows during pregnancy. Tincture of iodine may be injected under the skin or a suitable dose may be poured on the pregnant animal's back every 2 weeks during pregnancy. The most common method, and probably the simplest with swine, is to give iodine in the form of potassium iodide in the feed. (Sodium iodide may be used if it is cheaper.) It has been found that 2 grains of potassium iodide given to each sow daily during the gestation period will be sufficient to prevent the disease. A convenient way of administering the potassium iodide is to dissolve one ounce in a gallon of water. One tablespoonful of such a solution contains approximately 2 grains of the drug and is therefore a daily dose for a sow. The proper amount of this solution for the number of sows to be fed may be readily mixed with the feed each day. If more convenient, about 320 grains (two-thirds ounce, troy weight) of the dry potassium iodide may be mixed thoroly in each 1,000 lbs. of the concentrate mixture fed the pregnant sows.

918. Maintenance requirements of swine.—In experiments at the Wisconsin and Illinois Stations[9] Dietrich found that pigs could be maintained on 0.10 lb. digestible crude protein and 0.42 to 0.57 lb. total digestible nutrients per 100 lbs. live weight. This is 4.2 to 5.7 lbs. total digestible nutrients per 1,000 lbs. live weight, somewhat less than the amount required by the dairy cow or the steer, as is shown in Appendix Table V. This is probably due to the fact, previously pointed out (**90**), that maintenance requirements depend upon body surface, and since the pig is built more compactly than the steer or cow, he has less body surface per 100 lbs. live weight.

Faville of the Wyoming Station[10] found that brood sows weighing 314 lbs. at the beginning of the trial and 376 lbs. at the close made average daily gains of 0.4 lb. on a daily allowance of 4.6 lbs. of concentrates (2 parts corn and 1 part mill feed). This ration supplied only 57 per ct. of the nutrients called for by the Wolff-Lehmann standard.

919. Vitamine requirements; rickets.—Recent investigations have shown that there is much more chance of swine suffering from a lack of the fat-soluble vitamine than there is in the case of horses, cattle, or sheep. This is due to the fact that swine which are not on pasture are fed chiefly on grain and grain by-products, and nearly all the cereals, with the exception of yellow corn, contain little of this vitamine. (**104**) It is pointed out in the following chapter that young pigs fed such rations as white corn and skim milk without pasture usually fail to thrive after a time and many die from rickets or pneumonia. (**929**) These troubles may

[8]Mont. Bul. 119; Wash. Bul. 156, Pop. Bul. 117; Wis. Bul. 297.
[9]Wis. Rpt. 1899; Ill. Bul. 163. [10]Wyo. Bul. 96.

be prevented either by feeding yellow corn or by including 5 per ct. of well-cured, green-colored alfalfa hay in the ration, and probably by using hay from other legumes as well. The importance of legume hay for brood sows and pigs as well is emphasized in the following chapters. **(1009-11, 1016)** Without much question, the high value of legume hay for swine not on pasture is due not only to its richness in protein and calcium, but also to the fact that it is rich in the fat-soluble vitamine.

In the northern states pigs often suffer from rickets during winter, when they can not be on pasture. Animals thus affected become lame and crippled, especially in the hind legs, and in severe cases become permanently stunted or die. Rickets is a disease affecting the growing ends of the bones, and may be caused by a lack of calcium or phosphorus in the ration and also by the lack of a vitamine. As has been pointed out before, investigations have not yet conclusively shown whether the vitamine which prevents rickets is the fat-soluble vitamine or whether it is a fourth vitamine, the *anti-rachitic vitamine*. **(104)** In any event, experiments by Hart and Steenbock at the Wisconsin Station[11] show that legume hay and cod liver oil, which are rich in the fat-soluble vitamine, will usually cure rickets in pigs, if the case is not too far advanced. Whenever there is any evidence of this trouble in swine, 15 to 25 per ct. of choice legume hay should be included in the ration. In bad cases giving a teaspoonful of cod liver oil a head daily will usually be beneficial. On account of its value in preventing rickets, as well as its other beneficial effects, it seems wise, during winter in the northern states, to supply choice, leafy legume hay, preferably alfalfa, to brood sows and also fall pigs. **(1009-11, 1016, 1037)**

So far as is known, there is no necessity of paying any attention to the amounts of the water-soluble vitamine or of the anti-scorbutic vitamine in rations for swine. All ordinary rations contain plenty of the first, and swine do not have scurvy, even if fed on rations which would cause this disease if fed to humans, monkeys, or guinea pigs. **(104)**

920. Grinding or soaking grain.—Whether or not it pays to grind or crush the various grains for swine is a matter of great economic importance, and therefore naturally it has been given much careful attention by the experiment stations. As the following paragraphs show, the numerous trials which have been carried on to study this matter prove clearly that there is but little saving in feeding ground corn to swine in place of ear corn or shelled corn. For pigs under 150 lbs. in weight there was no appreciable saving at all thru grinding corn.

With the small grains, such as wheat, barley, oats, and the grain sorghums, more of the grain passes thru the animal unmasticated, and therefore grinding or crushing pays, even for pigs under 150 lbs. in weight. In the following chapter the saving which results from grinding or crushing the various grains is stated, so far as definite data are available. Where the small grains can not be conveniently ground, they should be

[11] Wis. Bul. 339, pp. 121-3; unpublished data.

soaked for about 12 hours before feeding, but should not be allowed to ferment.

921. Methods of preparing corn for pigs.—Pigs up to 140 to 150 lbs. in weight chew corn thoroly and therefore there is no appreciable saving in grinding the grain for them. After they reach this weight, they masticate the corn less completely and hence grinding or soaking the grain makes a slight saving in the feed required for 100 lbs. gain. These facts are clearly shown in trials by King at the Indiana Station[12] in which similar lots of pigs were fed either ear corn, shelled corn, or ground corn, the corn being supplemented with tankage and wheat shorts. Some lots were placed on experiment when the pigs weighed about 50 lbs., others at 85 lbs., and still others at 100 lbs., at 150 to 160 lbs., and at 210 to 220 lbs., respectively. The ear corn and shelled corn were fed dry and the ground corn was wet enough so that it would not be thrown out of the trough by the pigs while eating. The following table gives the results secured in these trials for two periods with pigs from 54 to 140 lbs. in weight, and then from that weight to an average weight of 221 lbs:

Effect of preparing corn for pigs of different weights

	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Pigs weighing 54 to 140 lbs.		
Ear corn	0.83	393
Shelled corn	0.81	398
Ground corn	0.83	393
Pigs weighing over 140 lbs.		
Ear corn	1.26	444
Shelled corn	1.27	452
Ground corn	1.39	425

The table shows clearly that up to a weight of 140 lbs. the pigs fed ground corn made no more rapid gains and required just as much feed for 100 lbs. gain as those fed ear corn. Also, ear corn gave slightly better results than shelled corn. There was therefore no advantage in shelling and grinding the corn for pigs up to this weight. The older pigs made a trifle more rapid gains on ground corn than on ear corn and required 4.3 per ct. less feed for 100 lbs. gain. However, even for pigs over 140 lbs. in weight, no saving of feed resulted from feeding shelled corn instead of ear corn.

Evvard conducted digestion trials with 60-lb. and 200-lb. pigs at the Iowa Station[13] to determine how completely pigs of these respective weights utilized corn prepared in various ways. The results of these trials are summarized in the following table:

[12]Am. Soc. Anim. Production, Proceedings, 1913, pp. 22-31.

[13]Information to the authors.

Percentage of dry matter digested with corn fed in various forms

	By 60-lb. pigs Per. ct.	By 200-lb. pigs Per ct.
Ear corn (not including cob)	88.8	85.4
Dry shelled corn	88.0	86.5
Soaked shelled corn	87.2	85.4
Dry ground corn	87.2	87.2
Soaked ground corn	85.9	88.4

The young pigs digested corn when fed as ear corn or dry shelled corn fully as well as when the dry ground corn was fed. With young pigs soaked ground corn gave the poorest results. With the 200-lb. pigs, on the other hand, grinding increased the percentage digested.

Many other trials have been carried on to determine the effect of grinding corn for swine. Henry, at first alone and later with Otis, conducted 18 trials at the Wisconsin Station[14] during 10 consecutive winters with pigs averaging 175 lbs. in weight at the beginning of the trials. In each trial one lot was fed a ration of two-thirds year-old shelled dent corn and one-third wheat middlings, and the other lot wheat middlings and the same corn ground to meal. In 11 of the trials grinding the corn saved from 2.5 to 18.5 per ct. in the amount of feed needed for 100 lbs. gain, while in the other 7 trials shelled corn gave the best results. On the average, with shelled corn it required 501 lbs. of concentrates (334 lbs. whole corn and 167 lbs. middlings) for 100 lbs. gain, while with ground corn it required only 471 lbs. of feed (314 lbs. corn and 157 lbs. middlings). Considering the saving both of corn and middlings which resulted from grinding corn, this preparation increased the value of the corn about 9.9 per ct. In recent trials by Vestal at the Indiana Station[15] and by Weaver at the Missouri Station,[16] grinding corn for well-grown pigs increased its value about 7 per ct.

Experiments by Kennedy and Robbins at the Iowa Station[17] show that ear corn produces just as rapid and economical gains as soaked shelled corn, dry ground corn, or soaked ground corn for young pigs. Furthermore for older pigs, merely soaking the shelled corn, which is inexpensive, gave just as good results as grinding it.

From these trials we may conclude that for young pigs there is no appreciable advantage in shelling, grinding, or soaking corn. Pigs weighing 140 to 150 lbs. or over may make slightly more rapid gains on soaked or ground corn and require somewhat less feed for 100 lbs. gain. Whether this saving, which will range from 4 to 10 per ct. and will probably average about 6 or 7 per ct., will cover the cost of preparation must be decided by the feeder.

922. Cooking feed.—Early agricultural authorities strongly advocated cooking feed for swine, but numerous trials at several stations have

[14]Wis. Rpt. 1906.

[15]Information to the authors.

[16]Information to the authors.

[17]Iowa Bul. 106.

proven conclusively that, instead of a gain from cooking, there is in nearly every case a loss. In 26 trials[18] in which pigs were fed either cooked or uncooked grain (corn, barley, rye, peas, or wheat shorts, fed separately or in combination), 89.4 lbs. of uncooked grain was as valuable, on the average, as 100 lbs. of the same grain when cooked, a loss of over 10 per ct. by cooking. Some few feeds, such as potatoes, field beans, and velvet beans are improved by cooking. In winter, slop should be warmed, but not cooked, for pigs in cold quarters.

923. Wetting or soaking feed.—There is generally not enough advantage in wetting feeds for pigs or in feeding concentrates in the form of a slop to justify the trouble, unless they will not otherwise drink enough water. When wheat meal is fed dry, it forms a pasty, gummy mass in the mouth, difficult to chew and swallow; feeding it as a thin slop largely prevents this trouble. To get the pigs to drink more water it may be desirable to feed concentrates in the form of a warm slop during winter in the North, if an automatic waterer with a heating device is not provided.

We have seen previously (**921**) that it may be advisable to soak shelled corn for large pigs, while this does not noticeably increase its value for young animals. Any grain so hard as to injure the mouths of the pigs during mastication should always be soaked if it can not be ground or rolled. This is especially necessary with such small hard grains as wheat and rye. In a trial at the Kansas Station[19] Kinzer and Wheeler found no advantage from soaking alfalfa meal and ground corn for fattening pigs.

924. Limited-feeding vs. full-feeding.—One of the most important questions that every hog raiser has to decide is how much grain he will feed his growing, fattening pigs. He knows that the larger the amount of grain or other concentrates he feeds them, the faster they will gain, no matter whether in dry lot or on pasture, but he wonders whether or not he will make more profit if he restricts the amount of concentrates.

In dry lot feeding, it is practically always most economical to full-feed growing and fattening pigs, unless it is desired to carry them along slowly for a later market. When pigs are fed about all they will eat, either by means of a self-feeder or by hand-feeding, they will consume less feed for each 100 lbs. gain up to market weights, and therefore the gains will be cheaper than if they had been fed less grain. This is because more time will be required to get the pigs to a given market weight, if the grain allowance is restricted. Every additional day requires just so much more feed merely to maintain the pig, for the feed used up in maintaining the body is lost so far as the actual production of pork is con-

[18]Me. State Col. Agr. Rpt. Trustees, 1876; Ontario School of Agr., Rpt. 1876; Kan. Agr. Col., Rpt. 1885; Iowa Agr. Col. Rpt. 1891; Wis. Rpt. 1886; Coburn, Swine in America.

[19]Kan. Bul. 192.

cerned. In spite of the time worn joke, "What is a pig's time worth, anyhow?" this matter is of much economic importance. Almost invariably it will be found that when pigs are not on pasture the more rapidly they can be made to gain by supplying them with an abundance of feed, combined in a properly balanced, economical ration, the cheaper will be their gains and the greater the resulting profit.

In summer feeding of spring pigs on pasture, the matter is more complicated. Pasture is usually cheap compared with grain or other concentrates. However, if the concentrate allowance is restricted, so as to make the pigs eat a larger proportion of forage, the gains will be much slower, and the pigs will not be ready for market until after the usual fall slump in prices has occurred. Many trials have been carried on at various experiment stations to study the economy of limiting the amount of grain for pigs on pasture, but most of the early trials covered only the pasture period. At the end of the experiments the full-fed pigs were ready for market or nearly finished, while those which had received less grain would have required fattening for several weeks in dry lot to get them to market weights. Such comparisons do not furnish a safe basis for conclusions, for as we have seen, much more feed is required per 100 lbs. gain during the finishing period than previously. (913) Therefore the pigs fed the limited rations still had their most expensive gains to make.

The following table summarizes the results of 8 trials in each of which one lot of spring pigs, weighing about 50 lbs. at the start, has been self-fed or hand-fed a full ration of corn and tankage on good pasture to an average market weight of 212 lbs., while another lot has been fed a limited allowance of corn and tankage until fall, when they were full-fed until they reached the same weights as the first lot. In one trial middlings was fed to both lots in addition to corn and tankage.

Limiting the concentrates during the summer for pigs on good pasture

Average ration	Daily gain Lbs.	Time to reach market weight Days	Concentrates for 100 lbs. gain	
			Corn Lbs.	Supplement Lbs.
*Lot I, full-fed entire time**				
Corn, 4.9 lbs. Supplement, 0.40 lb.....	1.34	122	361	32
*Lot II, limited ration in summer**				
Corn, 3.9 lbs. Supplement, 0.33 lb.....	1.04	156	372	34

*Av. of 4 trials by Morrison, Bohstedt, and Fargo, Wis. Station (Unpublished data); 2 by Evvard, Iowa Station (Information to the authors); 1 by Robison (Ohio Bul. 355); and 1 by Weaver, Mo. Station (Information to the authors).

The pigs full-fed from the start gained 1.34 lbs. a day and reached an average market weight of 212 lbs. in 122 days. It took the other lot, which received a limited allowance of corn at first, 34 days more to reach the same weight. A fact which will be surprising to many is that in these trials it actually required less corn and supplement to produce each 100 lbs. gain when the pigs were full-fed to market weights on good pasture than it did when the amount of corn was limited during the summer.

In other trials[20] where pigs have been fed limited rations in summer in comparison with others full-fed on concentrates, but in which the limited-fed pigs have not been carried to the same market weights, considerably more feed has been required per 100 lbs. gain by the full-fed pigs than by the others. As has been pointed out, this was because the limited-fed pigs were not yet well fattened.

Where the pasture is unusually good, as in the irrigated districts of the West, pigs may make the most economical gains if the grain allowance is limited. The following table summarizes the results of trials during 2 years by Arnett and Joseph at the Montana Station[21] in which 33-lb. pigs were fed various amounts of barley and tankage on irrigated pasture in summer. All lots were then full fed to a weight of 200 lbs.

Various amounts of barley for pigs on pasture

Daily concentrate allowance during summer	Daily gain	Time to reach 200 lbs.	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
1 lb. concentrates per 100 lbs. live wt.	0.84	201	354
2 lbs. concentrates per 100 lbs. live wt.	0.88	195	369
3 lbs. concentrates per 100 lbs. live wt.	0.94	182	374
Concentrates self-fed	1.02	170	400

In these trials the pigs fed only 1 lb. concentrates daily per 100 lbs. live weight during the summer and then full-fed in the fall took 201 days to reach the weight of 200 lbs.—31 days longer than the self-fed pigs. However, the self-fed pigs required 46 lbs. more concentrates per 100 lbs. gain.

925. Factors determining economy of full-feeding.—From all the experiments which have been carried on, we may conclude that it is generally most profitable in the corn belt and eastward to full-feed early spring pigs on pasture so they may be marketed in September or October before the slump in prices occurs. The advisability of this practice is shown by the following table which gives the average monthly receipts of hogs at the Chicago markets and the average price received per cwt. live weight for the 21-year period, 1901 to 1921, inclusive:[22]

Monthly receipts and average prices of hogs at Chicago

	Chicago receipts	Average price per cwt. live wt.
	Head	Dollars
January	888,000	8.17
February	759,000	8.43
March	646,000	9.04
April	531,000	9.16
May	605,000	9.00
June	603,000	8.83
July	552,000	9.28
August	484,000	9.27
September	423,000	9.36
October	535,000	8.75
November	701,000	8.23
December	858,000	8.00

[20]Evvard, Iowa Bul. 136; Robison, Ohio Bul. 343; Waters, Kinzer, and Wright, Kan. Bul. 192.

[21]Mont. Bul. 128.

[22]Wentworth, Progressive Hog Raising, p. 58.

The table shows that the lowest prices occur, on the average, in the months of December and January, due to the fact that the receipts are the heaviest during these months. An exceedingly important point is that the average price per cwt. in December is $1.36 less than for September and $0.75 below that for October.

Early spring pigs which are full-fed in summer on good pasture will usually be nearly ready for market before the corn crop is ripe in the fall. Therefore they can not utilize much of the new corn, which is normally lower in price than the old corn has been during the summer. However, if they can be marketed at good weights in September or October, the usual higher price will generally more than offset this factor.

Spring pigs which are to follow fattening steers in the fall and winter or pigs which are to hog down corn in the fall should not receive a full feed of grain in summer or they will be too heavy and too fat for these purposes. (**804, 942**) Young gilts or boars for the breeding herd should also be fed limited rations, as is pointed out later. (**1035**) In some cases it may be most economical to feed late spring or early summer pigs only enough concentrates on pasture to keep them growing thriftily, and then fatten them in the fall and early winter, so they will reach the market in February, when the price usually begins to rise again.

Numerous experiments have shown that if pigs are fed no grain at all on pasture they will, as a rule, little more than maintain their weight, and some will become stunted or even die. To keep spring pigs growing thriftily, even on excellent pasture, they must usually be fed at least 2 lbs. of concentrates daily per 100 lbs. live weight.

926. Self-feeding.—Largely thru the work of Evvard of the Iowa Station, the practice of self-feeding fattening pigs has become widespread during the past few years. Experiments at several stations have shown that this labor-saving method of feeding gives excellent results with growing, fattening pigs, with well-grown shotes, and with old sows which are being fattened. In self-feeding swine, grain and protein-rich supplements may be fed, free choice, in separate compartments of the self-feeder, or the pigs may be self-fed a properly balanced mixture of grain and protein-rich supplements. The merits of these two methods are discussed later. (**927**)

The self-feeder should not be used when rapid gains are not wanted, for instance, where it is desired to force pigs to make the maximum use of pasturage by limiting the grain allowance. If pigs are to be carried to weights of 275 lbs. or more before being marketed (which is not the common practice), it may be inadvisable to self-feed them until they reach the weight of 150 lbs. or more. Otherwise they may grow too fat at an early age. The self-feeder should not be used for growing pigs for the breeding herd, or for pregnant sows, unless some bulky feed, such as ground alfalfa, is mixed with the grain; else they will become too fat. Even when a bulky feed is included in the mixture, much skill is required

to keep the feeds so proportioned that the animals will not gain too much or too little. Therefore, as is pointed out in a later chapter, hand-feeding such animals is commonly preferable.

The following table summarizes the results of 17 trials at 6 different stations in each of which one lot of pigs, not on pasture, was self-fed corn and tankage, or else corn, tankage, and wheat middlings, free choice, in separate compartments of a self-feeder. Another lot in each trial was hand-fed a well-balanced ration of the same feeds, being given all they would clean up twice a day. In these trials a total of 314 pigs, averaging 86 lbs. in weight at the start, were included.

Self-feeding vs. hand-feeding pigs in dry lot

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain		
		Corn Lbs.	Supplement Lbs.	Total Lbs.
*Lot I, self-fed**				
Corn, 5.7 lbs. Supplement, 0.88 lb.....	1.58	359	56	415
*Lot II, hand-fed**				
Corn, 5.1 lbs. Supplement, 0.96 lb.....	1.42	356	68	424

*Av of 6 trials by Weaver (Mo. Bul. 144 and information to the authors); 5 by Robison (Ohio Bul. 355); 4 by Rice and Laible, Ill. Station (Information to the authors); 1 by Ashbrook and Gongwer (U.S.D.A. Farmers' Bul. 906); and 1 by McCampbell (Kan. Cir. 78).

It will be noted, first of all, that the self-fed pigs ate 0.6 lb. more corn a head daily than those which were hand-fed twice daily all they would clean up. This is the usual result and is due to the fact that self-fed pigs help themselves many times a day and even during the night, thus being "full-fed" at all times. Naturally they gained a trifle more rapidly than those which were hand-fed. Most important of all, is the fact that 9 lbs. less concentrates were required for 100 lbs. gain by the self-fed pigs. This is not a large saving in itself, but to it are added the advantages of the more rapid gains and the saving of labor by self-feeding. It will be noted furthermore that these self-fed pigs in dry lot ate less protein-rich supplement than the hand-fed pigs were given.

Self-feeding is also an economical method of feeding pigs on pasture. This is shown by the following table, which summarizes 9 trials in each of which one lot of spring pigs has been self-fed corn and tankage, free choice, on good pasture, while another lot has been hand-fed the same feeds. In these trials a total of 170 pigs, averaging 58 lbs. in weight at the start were fed for 112 days on the average.

Self-feeding vs. hand-feeding pigs on pasture

Average ration	Daily gain Lbs.	Concentrates for 100 lbs. gain		
		Corn Lbs.	Tankage Lbs.	Total Lbs.
*Lot I, self-fed**				
Corn, 4.6 lbs. Tankage, 0.38 lb.....	1.32	340	27	367
*Lot II, hand-fed**				
Corn, 4.2 lbs. Tankage, 0.28 lb.....	1.20	341	23	364

*Av. of 5 trials by Robison (Ohio Buls. 343 and 355); 2 by Evvard (Corn Belt Meat Producers' Assoc., Rpt. 1914, and information to the authors); and 2 by Snyder (Nebr. Bul. 165).

Just as in the trials in dry lot, the self-fed pigs ate more corn than those which were hand-fed, and made somewhat more rapid gains. On the average the self-fed pigs ate 4 lbs. more tankage per 100 lbs. gain, but took 1 lb. less corn. This slight difference of 3 lbs. total feed per 100 lbs. gain in favor of the hand-fed pigs would, however, ordinarily be more than offset by the saving in labor thru self-feeding and by the greater rapidity of the gains.

It should be pointed out that in all of these trials the hand-fed pigs were fed under the supervision of an experienced feeder. Under average conditions there would be a greater advantage in favor of self-feeding.

927. Free choice method of self-feeding.—When self-fed corn and tankage, free choice, pigs usually show a surprising ability to balance their own ration. When young, they eat a considerably larger proportion of tankage than they do during later periods. This can not be due to any profound knowledge of their own nutritive requirements and of the chemical composition of these feeds, for if fed other grains and other protein-rich supplements, they will fail at selecting the feeds in proper proportions to make a well-balanced ration. For example, barley is considerably richer than corn in protein; yet pigs self-fed barley and tankage, free choice, will nevertheless often eat a larger proportion of tankage than if they had been fed corn. Again, if pigs are self-fed grain and allowed to drink all the skim milk or buttermilk they wish, they will take much more milk than needed to balance the ration. On the other hand, if the protein-rich supplement is rather unpalatable, they will not eat enough of it, if it is fed free choice. For instance, when pigs are self-fed corn, linseed meal, and alfalfa hay in dry lot they will not infrequently fail to eat enough of the linseed meal to provide sufficient protein in their ration. (**973**) From these facts we may agree with Robison of the Ohio Station, who after a thoro study of this matter, states, "There is little question of the fallibility of the appetite of swine in enabling them to choose the feed stuffs or to select the proper proportions of the particular feeds before them to most nearly meet their physiological needs."

Most fortunately from the practical standpoint, it happens that self-feeding by the free choice plan works out well when corn is fed with tankage or fish meal as the supplement, and also when corn is fed with such mixtures as tankage and linseed meal, or tankage and corn germ meal. (**973, 980**) As a rule pigs will eat about the proper proportions of these feeds to make a well-balanced ration. Once in a while they will not eat nearly enough protein-rich supplement, or they may occasionally eat so much of the expensive supplement as to make the gains costly. In such cases the free choice plan of feeding had best be discontinued. Instead a suitable mixture may be self-fed or the pigs may be hand-fed.

In the following chapter the advisability of using the free choice plan of self-feeding is discussed under the various feeds, where data are

available. For example, it is pointed out that when pigs are fed ground barley and tankage, it is most economical to mix the barley and tankage in proper proportions for pigs of the given weight, rather than to self-feed the barley and tankage free choice. (**944**)

928. Water.—Swine, like all other classes of stock, should always be supplied with plenty of fresh water. The amount of water consumed by pigs ranges from about 12 lbs. daily per 100 lbs. of animal at weaning time down to 4 lbs. daily per 100 lbs. live weight during the fattening period.[23] Fresh water should always be supplied in a trough or an automatic waterer, except perhaps when the swine get an abundance of water in such watery feeds as slop or dairy by-products. Unless pigs are supplied water with the chill taken off in winter, they often do not drink enough.

929. Proprietary stock tonics; mineral and vitamine preparations.—In experiments which have been carried on at various experiment stations proprietary stock foods have proved uneconomical in practically all cases. For example in a trial by Grisdale at the Ottawa Experimental Farms[24] the value of three proprietary stock foods was tested when added to a mixture of half shorts and half mixed ground grains—peas, oats, and barley. In each case the use of the stock food materially increased the cost of the gains, and on the average the pigs fed no stock food made the better gains.

In trials at the Iowa Station[25] with International, Iowa, and Standard stock foods Michaels and Kennedy found that the stock foods when added to corn alone had no beneficial effect on digestion and that a bushel of corn produced as much or more pork when fed alone as when stock foods were added to it. (**289**)

At the Kansas Station[26] Kinzer and Wheeler fed International, Pratt's, and Hercules stock foods with corn to 170-lb. pigs in comparison with others fed corn alone and still others fed corn and tankage, or corn, tankage, and wheat shorts. The pigs fed corn and stock food made but slightly larger gains than those fed corn alone, while those fed corn and tankage, or corn, tankage, and shorts gained over twice as much as those fed corn alone. The wise farmer will not seek to use stock foods as a supplement to corn, but will employ such protein-rich feeds as skim milk, tankage, wheat middlings, and linseed meal.

It is pointed out elsewhere that before paying out money for any highly advertised stock tonic, mineral mixture, or vitamine preparation, the wise stockman will first secure unprejudiced advice from his experiment station. (**291-2**)

930. Winter vs. summer feeding.—In the South where pasture can be provided during all or most of the winter, there should be no difference in the cost of gains made by pigs in summer and in winter. However, in

[23]Dietrich, Swine, p. 156.
[24]Ottawa, Expt. Farms. Rpt. 1904.
[25]Iowa Bul. 113.
[26]Kan. Bul. 192.

the North winter gains are usually more expensive, especially with young pigs. This is because in winter no pasture can be provided to furnish cheap feed; and furthermore, due both to the lack of pasture and the cold weather, fall pigs are apt to be less thrifty than spring pigs on good pasture. (**1037**)

However, when fall pigs are properly fed and housed, they make economical gains, even in the northern states. For example, in 2 trials by Ferrin and McCarty at the Minnesota Station[27] 3 lots of fall pigs fed well-balanced rations in winter gained on the average 1.38 lbs. a head daily and required 404 lbs. concentrates for 100 lbs. gain. Three lots of spring pigs fed the same rations during spring and summer in dry lots, without pasture, gained 1.43 lbs. a head daily and required on the average 389 lbs. concentrates for 100 lbs. gain. Due to the fact that grain is usually somewhat lower in price in fall and winter than in summer, the feed cost of 100 lbs. gain was less for the fall pigs. Only when excellent rations are fed and when the pigs have suitable quarters can such good results be secured with fall pigs in the extreme northern states. Of course, if the spring pigs had been fed on pasture, as should always be the rule in economical pork production, their gains would have been considerably cheaper than those of the fall pigs.

Fall pigs will usually bring a higher price when marketed than spring pigs, for they should reach the market in spring when the supply is limited. (**925**) Under proper management this should largely offset the additional cost of the gains they make.

931. Shelter.—Even in the northern part of the corn belt where the winters are severe, inexpensive shelter is all that is necessary for swine. The requisites for healthful winter shelter are freedom from dampness, good ventilation without drafts on the animals, sunlight, reasonable warmth, and a moderate amount of dry bedding. The quarters should be located on well-drained ground and should be so arranged that they may be easily and thoroly cleaned and disinfected.

Swine may be housed in a central hog house with a number of pens or in small movable "cabins," or colony houses. Many use a combination of the two systems, for in the northern states the central house is well suited for winter shelter and spring farrowing, while the portable houses are particularly useful for housing pigs on pasture. Colony houses may also be used for winter shelter, and will be fairly warm if corn stalks, horse manure, or other litter is banked against the sides of the houses. A strong sack may be hung in the doorway to keep out the cold and yet allow the hogs to go back and forth.

Even in the northern states brood sows wintered in cheap colony houses do not require much more feed than those housed in a central house, especially if the houses are well protected. In trials during 4 winters by Morrison and Bohstedt at the Wisconsin Station[28] pregnant gilts were wintered in shed-roof colony houses made of a single thickness

[27]Information to the authors. [28]Unpublished data.

of boards. The opening thru which the sows entered was left open at all times so they could come and go at will and no litter was banked up against the houses to make them warmer. At farrowing time the sows were removed to farrowing pens in the central barn. The feed cost of wintering these sows was 16 per ct. higher than for sows kept in a central hog barn and allowed to run at will in an exercise paddock during the day. However, this increase in the feed cost was offset by the fact that 88 per ct. of the pigs from the sows in the colony houses were vigorous and only 74 per ct. of those wintered in the central house. This was probably due to the fact that the sows in the colony houses took more exercise. (**932, 1024**)

With young pigs warm winter quarters are more important. For example, Grisdale found at the Ottawa, Canada, Station,[29] where the winters are severe, that 70-lb. pigs housed in colony houses required 44 per ct. more feed for 100 lbs. gain than others in a well-built central hog house. Brood sows in the small houses required only 25 per ct. more feed than those in the warmer quarters, showing that large animals can withstand severe cold better than small ones. The health of the animals was good under both conditions. Shelton of the Kansas Agricultural College[30] found that during a winter in which the temperature at 8 a. m. ranged from 31° F. to –12° F. large hogs in warm quarters required 25 per ct. less feed than those in a yard protected only by a high board fence on the north.

Where the spring litters come in cold weather it is essential that fairly warm quarters be provided. If there is no central hog barn, a lantern hung in a well-protected colony house will furnish sufficient warmth.

932. Exercise.—For breeding stock and growing pigs ample exercise is of the utmost importance. To enforce exercise animals quartered in several cabins can be fed at a point, at some distance from the shelters, where there are troughs and a feeding floor. When snow covers the ground, paths can be broken out with a snow plow. On the feeding floor, which should be kept clean and should be covered, if possible, shelled corn and whole oats may be scattered thinly to force the sows or pigs to pick up a grain at a time. If a permanent hog house is used, abundant exercise should be enforced at all times with breeding and stock animals. (**1024**)

933. Types of swine; breed tests.—The principal breeds of swine are of two distinct types, the lard type, of which the Poland-China, Berkshire, Chester-White, and Duroc-Jersey are the leading breeds, and the bacon type, represented by the Tamworth and Large Yorkshire breeds. The Hampshires, tho often classed as bacon hogs, really stand between the extreme bacon type and the lard type. Lard hogs, which are the type commonly raised in the United States, have compact, wide, and deep bodies. Since the hams, back, and shoulders are the most valuable

[29]Ottawa Expt. Farms, Rpt. 1904. [30]Kan. Agr. Col., Rpt. Prof. Agr., 1883.

parts, the packer desires a hog furnishing a maximum of these cuts. Usually being well-fattened, lard hogs yield a high percentage of dressed carcass. Formerly heavy hogs were in largest demand, but now pigs weighing about 225 lbs. or less will command the highest price under usual conditions.

During the past few years the "big type" of the lard breeds has come into wide favor and is largely displacing the former extreme lard type. These hogs are more heavily and strongly boned, are longer and taller, and are more prolific. At a given weight they will carry less fat than the extreme lard type. Due to this and also to their greater vigor, they make more economical gains in weight. In trials by Evvard at the Iowa Station[31] big-type pigs have made more rapid and more economical gains to given market weights than extreme lard type pigs. The gains of the small-type pigs are especially costly after a weight of about 200 lbs. is reached, for they are then already very fat. Furthermore, there may be considerable difficulty in carrying pigs of this type to the heavier weights, because they seem more prone to pulmonary troubles.

The true bacon type is raised but little in the United States, the domestic demand for bacon being largely satisfied by the leaner pigs of the lard type. The bacon pig is raised chiefly in Denmark, Great Britain, and Canada, where corn is not the main feed for swine. Pigs of the bacon breeds are longer of body and of leg than those of the lard breeds, have less thickness and depth of body, and are lighter in the shoulder, neck, and jowl. The highest quality bacon is that made for the English market under the name of "Wiltshire side," which consists of the whole half of the dressed pig, less the head, feet, shoulder blade, neck bone, and aitch bone. For this purpose the pigs should weigh from 160 to 200 lbs. and carry but medium fat, which should be uniformly from 1 to 1.5 inches in thickness along the back.[32]

Breed tests have been conducted at several stations to determine whether there is any difference in the economy of meat production by the different breeds. Of these the most extensive were tests at the Ontario Agricultural College[33] and the Iowa Station,[34] in which pigs of the Berkshire, Poland-China, Duroc-Jersey, Chester-White, Tamworth, and Yorkshire breeds were compared. A study of the results shows that there was no consistent and uniform difference in gains or economy of production, a breed which ranked high in some of the tests, being surpassed by other breeds in the rest of the trials. The bacon breeds made as economical gains as those of the lard type. We may conclude that there is no best breed of swine so far as rate and economy of gains are concerned. There are far greater differences between individuals of the same breed than between the different breeds. One should select the breed which

[31]Iowa Rpts. 1918, pp. 19–20; 1919, pp. 19–20; 1920, p. 23.
[32]Day, Productive Swine Husbandry, pp. 13–14.
[33]Ont. Agr. Col., Rpts. 1896–8.
[34]Iowa Bul. 48.

seems best adapted to his conditions and suits his fancy, and then be sure to secure and to maintain vigorous, well-bred animals of that breed.

Assertions were formerly often made that razorbacks, or the semi-wild swine of the South, were immune to hog cholera and made very economical gains. In trials by Carlyle at the Wisconsin Station[35] neither of these claims proved true. Statements that the mule foot breed is immune to hog cholera are also unfounded.

The length of the intestines in modern domestic hogs is apparently longer in proportion to body length than in wild hogs. This indicates that the improved hog can digest his food more thoroly than his ancestors, and also that he can eat a larger quantity of food for his size. Cuvier[36] reported many years ago that the total length of the intestines of the wild boar was 9 times the body length; in the domestic boar, 13.5 times; and in the Siam boar 16 times the body length. Henry[37] found the average length of the intestines of 39 fattening hogs to be about 21 times the body length.

934. Dressing percentages.—Hogs dressed "packer style" with the head off, and also the leaf fat, kidneys, and ham facings removed, will usually range in dressing percentage from 66 to 75 per ct., or even more in the case of very fat barrows. On the average the dressing percentage of the swine slaughtered at the large packing plants is about 68 to 70 per ct. When hogs are dressed shipper style, with heads on and without the leaf fat, kidneys, and ham facings being removed, the dressing percentage will usually range from 73 to 85 per ct. or more, depending on the age of the hog and the degree of fatness.

935. Barrows vs. sows.—It is commonly believed that barrows will make a little more rapid and economical gains than open sows, due to the restlessness of the sows during the oestrum periods. Up to the usual market weights there is, however, apparently no appreciable difference in the gains of gilts and barrows. This is indicated in experiments carried on during several years by Morrison, Bohstedt, and colleagues at the Wisconsin Station.[38] In these trials pigs were fed well-balanced rations, either in dry lot or on pasture. The trials were usually begun when the pigs weighed 50 to 70 lbs., and they were carried to market weights of 200 lbs. to 225 lbs. In these experiments 601 barrows gained on the average 1.28 lbs. a head daily, while the average gain of 469 gilts was 1.26 lbs. The slightly more rapid gains of the barrows were, no doubt, due to the fact that somewhat more gilts than barrows were retained for breeding stock and not fattened for market in the experiments. Thus the barrows in the trials tended to average a trifle better in individuality than the gilts.

[35]Wis. Rpt. 1903.

[36]Darwin, Animals and Plants under Domestication.

[37]Wis. Rpt. 1889.

[38]Unpublished data compiled by DuRant and Heebink.

MANY SWINE RAISERS HAVE DISCARDED THE SLOP BUCKET

There is generally not enough advantage in wetting feeds for pigs or in feeding concentrates in the form of a slop to justify the expense.

SELF-FEEDERS SAVE LABOR IN FATTENING PIGS

Pigs self-fed suitable rations make exceedingly economical gains. However, the free-choice method of feeding is not satisfactory with some feeds. See Page 615.

COLONY HOUSES BANKED WITH STRAW FOR WINTER

Colony houses thus protected provide comfortable winter quarters for all but small pigs, even in the northern states.

BROOD SOWS HOUSED IN COLONY HOUSES AT WISCONSIN STATION

Brood sows housed in these unprotected colony houses required 16 per ct. more feed than those kept in a central hog house, but the percentage of vigorous pigs they farrowed was higher, because they took more exercise.

Spaying sows before fattening them is of no advantage, for unspayed sows apparently make just as good gains.[39]

936. Bacon production.—In northern Europe, especially Denmark and Ireland, raising bacon-type pigs and feeding them so as to produce the highest quality of bacon, is an industry of great importance. Also in Canada many of the hogs are of bacon type and are fed so as to produce high quality bacon for export and domestic consumption. In the United States, however, nearly all the swine are of the lard breeds and the bacon on the market is therefore obtained chiefly from lard-type pigs which do not carry too much fat.

For the production of high-quality bacon, the carcass should show much less fat in proportion to lean meat than in fat lard hogs, and the fat must be white, firm, and solid. According to Day,[40] a peculiar feature of swine is their tendency to develop fat. If the very best specimens of the bacon type are fed largely on corn, in a couple of generations they will show a tendency to become shorter and thicker in body. "Even under the most favorable conditions there is a tendency for the bacon type to change gradually in the direction of the fat type, unless care is exercised in selection. It is safe to say, therefore, that it is easier to increase the proportion of fat in a hog's carcass than it is to increase the proportion of lean, and that the extent to which the lean may be increased by the character of the feed is very limited and is fixed by the individuality of the animal." (133)

Even a slight degree of softness, which would not be very objectionable in a lard hog, will disqualify a carcass for prime bacon. Therefore, if bacon production is made a specialty, great care is necessary to produce a hard, firm carcass.

The extensive studies of Fjord and Friis of the Copenhagen (Denmark) Station,[41] and those of Day, Grisdale, and Shutt of the Canadian Stations,[42] show that soft pork unsuited to the production of high quality bacon is due on the part of the animal to unthriftiness, lack of exercise, immaturity, or lack of finish, and only in a small way to the breed. Imperfect feeding, marketing before being finished, and excessive fattening are other causes. In general, improper feeding stuffs and feeds improperly combined tend to produce low-quality bacon.

Barley ranks first for bacon production, followed by oats and peas. Skim milk and whey in combination with the cereal grains, including corn in limited amount, make good bacon. Corn, beans, soybeans, peanuts, and rice by-products all tend to produce soft bacon. While corn appears to give a good quality of meat in the case of the lard hog, it must be remembered that the bacon hog is marketed at lighter weights and in thinner condition than the lard hog, which may possibly explain

[39]Foster and Merrill, Utah Bul. 70.

[40]Productive Swine Husbandry, p. 13.

[41]Copenhagen (Denmark), Rpts. 1884, et. seq.

[42]Rpts. and Buls. of Ont. and Ottawa Expt. Stations, 1890–96.

why corn is unsatisfactory for feeding bacon hogs. Good pasture, such as rape, clover, or alfalfa, and also roots in winter are very helpful in producing good bacon carcasses, but too much succulent feed and with only a little concentrates will produce soft bacon. For choice bacon, however, pigs are usually fed slightly less concentrates than a full ration. Growthy, thrifty pigs that have been properly fed to a weight of 100 lbs. and that have had plenty of exercise may be finished on almost any of the common concentrate mixtures and make fine bacon.

CHAPTER XXXIV

FEEDS FOR SWINE

I. Carbonaceous Concentrates

During the past few years remarkable advances have been made in our knowledge concerning the feeding of swine. This is because the recent discoveries in animal nutrition and stock feeding are of far greater importance in pork production than in most other phases of animal husbandry. Swine are fed chiefly on corn and other cereal grains and usually eat relatively little roughage except when on pasture; furthermore, they grow more rapidly than other classes of stock and produce young when less mature. Hence they suffer more frequently than cattle, horses, or sheep from a lack of the right kind of proteins or from deficiencies of mineral matter or of the fat-soluble vitamine.

We shall learn in this chapter that many rations which, a few years ago, were considered satisfactory have been shown by careful experiments to be strikingly inefficient under certain conditions. Therefore, in order to secure maximum profits from hogs, it is necessary not only to feed "balanced rations," which supply enough digestible crude protein, but also to supply combinations of feeds which meet the more recently discovered nutrient requirements. Fortunately, investigations have shown that for success in pork production it is not necessary to feed complicated or expensive rations. All that is needed are common feeding stuffs properly combined in the manner pointed out later.

937. Indian corn.—This imperial fattening grain is the common hog feed in the great pork-producing districts of America. Not only is it usually the cheapest carbonaceous feed available in the corn belt, but it is exceedingly palatable to swine and produces unrivaled results when fed in properly balanced rations. Often, however, poor results are secured because swine raisers do not realize the limitations of corn and do not supply other feeds which will make good its deficiencies. We have learned in previous chapters that corn is not only low in protein but that the proteins are also unbalanced in composition; i. e., they contain too small proportions of some of the amino acids necessary for maintenance and growth. Corn is also exceedingly low in calcium and contains only a fair amount of phosphorus. Moreover, white corn contains little or none of the fat-soluble vitamine. In feeding corn all of these facts must be kept clearly in mind. (201-2)

The proteins in most protein-rich concentrates of plant origin, such

as linseed meal, wheat middlings, gluten feed, corn germ meal, etc., are unbalanced in somewhat the same manner as the proteins of corn and the other cereals. In other words, these feeds, tho they are rich in protein, do not furnish enough of those amino acids which are deficient in the cereal grains. Hence, if young pigs which are not on pasture are fed only corn or other grain, supplemented by such feeds as linseed meal or wheat middlings, they will fail to make good gains. This will be true even if there is supplied some mineral supplement that furnishes calcium, in which such rations are also low. Skim milk, buttermilk, whey, tankage, and fish meal, all of which are of animal origin, supply proteins which are admirably suited to supplement corn, for they are rich in the very amino acids that are deficient in the cereal grains. Furthermore, all these feeds, except whey, are rich in calcium. Therefore, especially for young pigs not on pasture, much better results are secured when one of these feeds of animal origin is included in the ration.

Fortunately, good pasture crops, such as alfalfa, clover, and rape, are all rich in proteins and also the proteins balance the proteins of the cereal grains quite well. Furthermore, such green crops are also high in calcium. Therefore, for pigs on pasture protein-rich supplements of plant origin, such as linseed meal or wheat middlings, may give nearly as good results as skim milk or tankage.

It is pointed out later that for feeding pigs which are already well grown, weighing 125 lbs. or over, rations of grain supplemented by such feeds as linseed meal or wheat middlings may give fair results, even with pigs not on pasture, since animals of this weight are growing less rapidly in protein tissues. However, more rapid and cheaper gains are usually secured, even with such older pigs, if care is taken to supply a ration in which the proteins are better balanced. (**969, 973**)

938. Correcting the deficiencies of corn.—No single fact in stock feeding has been more clearly demonstrated by numerous feeding trials than that corn alone gives exceedingly poor results when fed to growing and fattening pigs. A glance at the following table should convince any farmer of the folly of feeding such an inefficient ration. This summarizes the results of 7 trials in which corn alone, without pasture, has been fed to young pigs, averaging 69 lbs. in weight, in comparison with a balanced ration of corn and tankage. The results are also given for 15 similar comparisons of corn alone versus corn and tankage for older pigs, averaging 148 lbs. in weight when the experiments began.

In the trials in which young pigs were fed corn alone, they gained only 0.59 lb. a head daily and required 642 lbs. of corn for each 100 lbs. gain. This was a poor showing, indeed, but the results would have been even worse if the pigs had been started on this inadequate ration when still younger. When corn was balanced with tankage, the gains were doubled, and only 387 lbs. corn and 42 lbs. tankage were consumed for each 100 lbs. gain. Futhermore, at the end of the trials, the pigs fed corn alone were usually stunted and averaged only 141 lbs. in weight,

while those fed tankage in addition weighed over 200 lbs. and were ready for market.

The older pigs averaged 148 lbs. in weight when the experiments began, and hence could stand the ration of corn alone somewhat better. Nevertheless, they gained only 1.03 lbs. a head daily, while those fed tankage in addition gained 1.59 lbs. There was also nearly as great a difference in the feed required for 100 lbs. gain as in the case of the younger pigs.

Corn alone vs. corn and tankage for growing, fattening pigs

Average ration	Average length of trials	Daily gain	Feed for 100 lbs. gain	
			Corn	Tankage
	Days	Lbs.	Lbs.	Lbs.
Trials with young pigs				
Lot I, corn alone				
Corn 3.5 lbs.	122	0.59	642	..
Lot II, corn and tankage				
Corn, 4.4 lbs.				
Tankage, 0.48 lb.	122	1.18	387	42
Trials with older pigs				
Lot I, corn alone				
Corn, 5.7 lbs.	69	1.03	617	..
Lot II, corn and tankage				
Corn, 6.1 lbs.				
Tankage, 0.67 lb.	66	1.59	400	43

The folly of feeding such an unbalanced ration as corn alone is shown by the fact that in these trials 100 lbs. of tankage saved 607 lbs. of corn with the younger pigs and 505 lbs. of corn with the older ones. It is shown later in this chapter that even when pigs have good pasture in addition to corn, better results are secured when some protein-rich concentrate is added to the ration, to balance it more completely. Corn alone is fairly satisfactory for fattening old sows, for they have completed their growth and hence need less protein. However, even here the use of some supplement will usually produce cheaper gains.

From the fact that the value of tankage as a supplement to corn has been emphasized in this discussion, it must not be concluded that tankage is superior to other protein-rich supplements. Skim milk, buttermilk, fish meal, and combinations of other feeds will give fully as good results, as is pointed out later in this chapter. In fact, for young pigs not on pasture, tankage fed as the only supplement to corn does not usually produce as rapid gains as such combinations as tankage, linseed meal, and chopped alfalfa or tankage and corn germ meal. (966)

Corn alone is just as unsatisfactory for pregnant sows as it is for young pigs, as is pointed out in the next chapter. (1014) Farmers who persist in wintering their sows on this poor ration have no basis for complaint if their pig crop is a failure. On account of the poor results which have been secured with corn improperly fed, many breeders recommend that not over one-third to one-half the ration for brood sows

consist of this grain. However, good results have been secured in numerous trials where corn has been the chief feed, but where the allowance was restricted so that the sows did not become too fat and the ration was properly balanced by furnishing such feeds as legume hay and tankage or dairy by-products. (1019)

In the corn belt corn is usually fed on the cob. This is a wise practice, for, as we have seen in the previous chapter, there is no appreciable advantage in shelling, grinding, or soaking corn for pigs under 150 lbs. in weight, and even for older ones the slight saving will not usually pay for such preparation. (920)

If pigs are to hog down immature corn in the fall or are to be fed such grain in the yard, the change should always be made gradually: otherwise digestive disturbances are apt to result. Immature corn is more fermentable than mature grain, and is apt to cause diarrhea unless this precaution is taken. Contrary to a common belief, new corn does not cause hog cholera. However, pigs which have become unthrifty due to improper feeding of new corn, are more susceptible to the disease if they are exposed to infection.

On account of the great storage of nutrients in the corn grain during the latter stages of growth, an acre of standing corn will make much more pork if fed after the grain begins to dent than it will if fed off when in the roasting ear stage. When the kernels have dented, little trouble will be experienced in changing pigs to new corn, and in fact they will appreciate a change from dry, hard old corn. If the pigs are to be marketed within a week or so after new corn is ready, they had best be continued on their former ration if there is still old corn on hand, as a change might lessen the gains for a few days.

939. Yellow versus white corn.—Whether there is any difference in the feeding value of yellow and white corn is a question which has often been discussed by farmers and scientists alike. The general conclusion until 1920 was that there was no difference whatsoever. Then Steenbock discovered at the Wisconsin Station[1] that yellow corn contains considerable of the mysterious fat-soluble vitamine, which is present in butterfat, while white corn contains little or none. (104) As soon as this was learned, experiments were begun by Morrison, Bohstedt, and Fargo at the same station[2] to find what difference, if any, there was in the feeding value of the two kinds of corn.

Since it had already been discovered that the green-leaved parts of plants contain large amounts of this same fat-soluble vitamine, it did not appear probable that there could be any difference in the feeding value of the two kinds of corn for animals which ate plenty of pasture or good, green hay. Therefore, experiments were undertaken chiefly with pigs fed in dry lots, where they had no fresh, green feed.

Five trials have been conducted with pigs started at weights of 50 to

[1]Jour. Biol. Chem., 41, 1920, pp. 81–96; Wis. Bul. 319, pp. 50–1.

[2]Wis. Buls. 323, pp. 10–11; 339, pp. 125–9; unpublished data.

60 pounds and fed to the market weight of 200 pounds. The results show clearly that yellow corn produces decidedly larger and more economical gains than white corn when fed to young pigs *not on pasture*, with such supplements as skim milk, whey or linseed meal, none of which are rich in the fat-soluble vitamine. For pigs on excellent pasture there was no difference in the value, due to the fact that green plants are rich in the fat-soluble vitamine. However, in the fall, when the pasture season was over, the pigs on white corn soon began to fall behind those receiving the yellow corn. Even when fed with tankage or meat meal, which may perhaps contain some fat-soluble vitamine, yellow corn has usually been considerably better than the white corn for young pigs.

When young pigs have been fed white corn with skim milk as the only supplement, disastrous results have often followed. This is due to the fact that skim milk from centrifugal separators is always low in the fat-soluble vitamine. Therefore, white corn and skim milk fed in dry lot without green feeds make a ration very deficient in this vitamine. Many pigs have died from rickets or from pneumonia after several weeks on this inadequate ration, and those which did not succumb made poor gains. On the other hand, pigs fed yellow corn and skim milk were vigorous and thrifty.

Adding a small amount of good, leafy alfalfa hay to a ration lacking in the fat-soluble vitamine apparently corrects the deficiency. For example, pigs fed skim milk and a mixture of 95 lbs. white corn and 5 lbs. chopped alfalfa remained thrifty and made just as rapid and economical gains as others fed yellow corn. In all probability hay from other legumes would serve the same purpose. Only 5 per ct. of hay was fed, as more hay would have made the ration too bulky and high in fiber for young pigs.

These trials and also experiments by Mitchell and Emmett at the Illinois Station,[3] and a trial by Loeffel at the Nebraska Station,[4] show the inferiority of white corn for young pigs when not supplemented by some feed rich in the fat-soluble vitamine. For pigs over 100 to 125 lbs. in weight there is probably much less difference in the value of yellow and white corn, especially if they have had good pasture previously. When animals are supplied feeds rich in the fat-soluble vitamine, as is the case with pasture crops, they store considerable amounts in their livers and certain other organs. This stored supply will aid in carrying them thru the fattening period, even tho their ration then furnishes little of the vitamine. Even with young pigs fed in dry lot, a ration of white corn and such supplements as skim milk or tankage will usually give good results for a few weeks, if the pigs have been on pasture previously. It is possible that brood sows may suffer from a lack of the fat-soluble vitamine during winter in the northern states if they are fed white corn and other feeds lacking this essential. However, giving them plenty of legume hay will remedy any such deficiency.

[3]Information to the authors.

[4]Information to the authors.

Sows will commonly eat plenty of alfalfa hay of good quality if it is fed uncut in a suitable rack where they have access to it at all times. They usually do not like clover hay nearly so well as alfalfa. Young pigs will not eat much long alfalfa from a rack, and often will not take enough to provide a sufficiency of the fat-soluble vitamine. When sows or pigs fed white corn will not eat about 5 per ct. as much legume hay as they do of corn, it may be necessary to chop the hay and mix it with their concentrates to force them to eat it. This may be done at small expense by running it thru a silage cutter, preferably equipped with an alfalfa screen. If one does not have a suitable cutter, he can scrape up the leaves and chaff from the floor where the legume hay is pitched down from the mow, and mix this with the corn and skim milk or other feeds to form a slop.

940. Soft corn.—In the northern states when killing frosts come before corn is mature it is a problem to utilize the grain fully. Such soft corn may contain 30 to 50 per ct. water and is unsalable, for it will not keep in storage. It can be utilized best for stock feeding and is excellent for swine. Pound for pound, the dry matter in soft corn is equal to that in mature corn. In a trial by Evvard at the Iowa Station,[5] 100 lbs. of dry matter in immature "sample" grade corn containing 21.3 per ct. moisture was worth fully as much as the same amount of dry matter in old corn. Soft corn may usually be used during cold weather without danger, but should not be carried over into spring, as it will spoil and become unfit for use. (**205**)

941. Corn-and-cob meal; corn feed meal.—The labor involved in grinding ear corn to corn-and-cob meal is more than wasted, for in trials at the Iowa Station[6] pigs made larger and more economical gains on ear corn. This seems reasonable, for the pig has a digestive tract that can at best but poorly utilize a hard, fibrous material such as the corn cob, altho it has been ground. Even for brood sows, where a bulky ration is desirable, it is much better to supply the bulk by feeding legume hay than by using corn-and-cob meal, for the hay furnishes not only bulk but also protein and mineral matter. (**208**)

Corn feed meal, which is the by-product obtained from the manufacture of cracked corn and table meal, proved equal to ground corn in trials by Skinner and Starr at the Indiana Station.[7]

942. Hogging down corn.—In the corn belt many farmers turn pigs into standing corn, in which rape or other supplemental crops have usually been sown, and allow them to do their own harvesting. Instead of this being a wasteful practice, as many have thot, careful experiments have shown hogging down to be an economical method of fattening pigs.

In each of 6 trials which are summarized in the following table, one

[5]Information to the authors.

[6]Kennedy and Robbins, Iowa Bul. 106.

[7]Ind. Bul. 219; Smith, Pork Production, p. 304.

lot of pigs was fattened in the corn field and another lot fed ear corn in a yard. In addition, all the pigs were fed either tankage or wheat middlings. To furnish additional feed and help balance the ration, rape was seeded in the corn field at the last cultivation in 4 of the trials, and rye in another. The corn consumed by the pigs in the corn field was estimated by husking representative rows, and in the table all the corn has been reduced to the basis of well-cured shelled corn.

Hogging down corn compared with feeding corn in yard

	No. of pigs	Av. length of trial Days	Daily gain Lbs.	Concentrates for 100 lbs. gain Lbs.
Lot I, Hogging down corn*.....	109	43	1.59	478
Lot II, Fed ear corn in yard*.....	72	46	1.50	511

*Average of 2 trials by Gaumnitz, Wilson, and Bassett(Minn. Bul. 104); and 1 trial each by the following: Evvard (Iowa Bul. 143); Ferrin and Jessup, Minn. Station (Information to the authors); Robison, Ohio Station (Information to the authors); and Vestal, Ind. Station (Information to the authors).

The pigs hogging down the corn crop made slightly more rapid gains than those fed ear corn in the yard and required 6 per ct. less concentrates for 100 lbs. gain. When we consider these results, it is no surprise that most corn-belt farmers who have tried hogging down corn are in favor of the practice. Unless the weather is unfavorable, the pigs will pick up the corn as closely as is usually done in husking.

Where corn is to be hogged down, it is always advisable to grow some supplemental feed with the corn, or else to allow the pigs access to good alfalfa, clover, or rape pasture in addition. The most common crop used is rape, seeded in the corn at the time of the last cultivation. Unless there is a midsummer drought, the rape will make considerable growth and aid materially in balancing the ration. Other crops used are soybeans or pumpkins, planted with the corn, or rye, seeded at the last cultivation. Rape may be grown more cheaply than soybeans or rye, and usually gives better results.

Even when supplemental feed is grown in the corn field, it is usually most profitable to feed in addition 0.2 to 0.3 lb. per head daily of tankage or enough of some other protein-rich supplement to furnish an equal amount of protein. For example, in a trial by Robison at the Ohio Station,[8] pigs hogging down corn in which rape or soybeans had been grown gained 1.28 lbs., while others fed 0.3 lb. tankage a head daily in addition gained 1.81 lbs. Adding the tankage increased the gross return per bushel of corn by 18 cents, after deducting the cost of the tankage fed.

Adding a protein-rich supplement is of even more importance than growing a supplemental crop in the corn field. Thus in 5 Ohio trials by Robison,[9] pigs fed tankage while hogging down corn in which no supplementary crop had been grown gained 1.82 lbs. a head daily and

[8]Information to the authors.

[9]Am. Soc. Anim. Production, Proc. 1921, pp. 48–54.

consumed only 417 lbs. corn grain and 18 lbs. tankage for 100 lbs. gain. Other pigs on corn in which soybeans had been grown, but fed no tankage in addition, gained only 1.31 lbs. a head daily and required 574 lbs. corn for 100 lbs. gain. When tankage and other suitable protein-rich feeds are high in price, it may be most economical to let pigs which are hogging down corn have access to good alfalfa, clover, or rape pasture and then feed no other supplement in addition. The gains will usually be less rapid under this system, but they may be cheaper.[10] It is especially necessary to feed a protein-rich concentrate when the pigs are furnished no supplementary green feed. For balancing the ration where no such crops have been grown with the corn, supplements of animal origin, including tankage, skim milk, buttermilk, whey, and fish meal, are better than such feeds as linseed meal, soybean seed, or wheat middlings.

Spring shotes, well grown on pasture and weighing 90 to 130 lbs. at the start, are best for hogging down. Lighter pigs may be used if a few heavy hogs are put with them to break down the corn. Many turn in sows and their pigs after the shotes are removed, to clean up what little corn is left—a good practice, for it makes the pigs take plenty of exercise.

It is best to confine the pigs to limited areas of the field by fencing, so that they will clean up the corn in 20, or better, 14 days. Older hogs should be confined to smaller areas than shotes, for otherwise they will knock down and waste more corn. Woven wire is used for fencing, being tied to corn stalks and further supported by posts or stakes where necessary. According to the Minnesota Station,[11] pigs weighing 125 lbs. at the beginning will clean up 1 acre of corn in the time shown in the following table:

Number of days required by pigs to clean up 1 acre of corn

	Yield, 40 bu. per acre Days	Yield, 50 bu. per acre Days	Yield, 60 bu. per acre Days	Yield, 70 bu per acre Days
When 20 pigs forage	15	19	23	26
When 40 pigs forage	8	9	11	14
When 60 pigs forage	5	6	8	9
When 80 pigs forage	4	5	6	7

Field feeding of corn is most successful when the weather is dry. It is not wise to keep pigs in the fields after heavy rains, for they then waste corn and may injure the land. Unless very early varieties of corn are used, which are usually not heavy yielders, the new corn crop will not be ready early enough in the fall to furnish much feed for pigs which are to be finished for market in September or October, before the usual slump in prices occurs. Such pigs must be fattened chiefly on old corn. Breeding stock should never be used to hog down corn, as they will get too fat.

[10]Holden, Nebr. Bul. 159.

[11]Minn. Bul. 104.

943. Hominy feed.—In the early trials with hominy feed, this corn by-product was apparently worth more than corn per 100 lbs.[12] However, in later experiments hominy feed has ranked slightly below corn for swine feeding, instead of proving superior. This is doubtless due to the fact that the milling process has been changed so that the hominy feed now produced is apt to be slightly higher in fiber and often lower in fat than that of several years ago. (**213**)

In 6 recent experiments hominy feed and tankage have been self-fed, free choice, to pigs on good pasture, in comparison with shelled corn and tankage, which were fed similarly. In these trials pigs averaging 63 lbs. in weight were fed for an average of 105 days with the following results:

Hominy feed vs. corn for pigs on pasture

Average ration	Daily gain	Feed for 100 lbs. gain	
		Corn or hominy feed	Tankage
	Lbs.	Lbs.	Lbs.
*Lot I, hominy feed**			
Hominy feed, 4.7 lbs.			
Tankage, 0.37 lb	1.35	352	28
*Lot II, corn**			
Shelled corn, 4.8 lbs.			
Tankage, 0.44 lb	1.43	334	32

*Average of 5 trials by Evvard, Dunn, and Culbertson, Iowa Station (Information to the authors), and 1 trial by Gramlich (Nebr. Bul. 176).

In these trials the pigs fed hominy feed made a trifle less rapid gains and required a little more hominy feed for 100 lbs. gain than the corn-fed pigs did of grain. However, the pigs fed corn consumed a little more tankage. Considering both factors, hominy feed was worth 98 per ct. as much a ton as shelled corn, with corn at 56 cents a bushel and tankage at $60 a ton.

In 5 recent trials[13] in which hominy feed has been compared with corn for dry lot feeding, with tankage or skim milk as the supplement, it was worth on the average only about 93 per ct. as much a ton as corn. Considering all the data available, it is safe to conclude that unless the price of hominy feed is at least 3 to 7 per ct. below that of well-cured corn per ton, it will be less economical for swine feeding. When pigs are self-fed hominy feed and tankage by the free-choice method, they sometimes eat considerably more tankage than is needed to balance their ration. In such cases the tankage had best be hand-fed.

White hominy feed has sometimes brought a higher price on the market than yellow hominy feed. This is illogical, for it is low in fat-soluble vitamine, just as is the white corn from which it is made. Thus, under certain conditions, it will be worth less, rather than more, for swine feeding. (**939**)

[12]Skinner and King, Ind. Bul. 158; Eastwood, Ohio Bul. 268.

[13]Gramlich and Loeffel, Nebr. Bul. 175 and information to the authors; Robison Ohio Monthly Bul. 57; Skinner and Starr, Ind. Bul. 219.

944. Barley.—Tho corn is the mainstay of pork production in the greater part of the United States, in Canada and Europe barley is the most common grain for swine. It has there gained a high reputation for the production of bacon of prime quality. In this country barley is widely used as a hog feed in the northern states, where this cereal commonly excels oats in the weight of grain yielded per acre on fertile soil. (226) Since barley is considerably richer than corn in protein, less protein-rich supplement is needed to balance the ration when barley is fed. Just as in the case of corn, however, the proteins of barley are unbalanced in composition, and also the grain is low in calcium. Therefore for pigs not on pasture, such rations as barley and only wheat middlings or linseed meal do not usually give as large or as economical gains as where some feed of animal origin or else some legume hay is added to the ration. For example in 2 trials by Morrison and Bohstedt at the Wisconsin Station[14] pigs weighing 125 to 150 lbs. at the start, which were self-fed barley and standard wheat middlings, gained only 1.21 lbs. on the average. On barley and skim milk other lots gained 1.89 lbs.; on barley and whey, 2.22 lbs.; and on barley and tankage, 1.64 lbs. Poor results were also secured when linseed meal alone was used as the supplement to barley, even when a mineral supplement was added to supply additional calcium.

Because it carries the hull, ordinary brewing or feed barley is a less concentrated feed than corn, and consequently is not quite equal to corn, pound for pound, for swine feeding. However, plump, heavy barley, when ground, closely approaches corn in feeding value for fattening pigs, as the following table shows. This gives the results of 8 trials at northern stations in which pigs, averaging 109 lbs. in weight, have been self-fed ground barley and tankage in dry lots in comparison with others fed corn and tankage, for an average of 66 days:

Ground barley vs. corn for fattening pigs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Grain Lbs.	Feed for 100 lbs. gain Tankage Lbs.
Lot I,* Barley, 6.3 lbs. Tankage, 0.43 lb.....	1.44	439	30
Lot II,* Corn, 6.4 lbs. Tankage, 0.64 lb	1.64	389	39

*Average of 5 trials by Brown, Mich. Station (Information to the authors); 2 by Morrison and Bohstedt, Wis. Station (Wis. Bul. 319, pp. 67-8); and 1 by Ferrin and Carnes, Minn. Station (Duroc Digest, Nov. 1, 1921).

In these trials the pigs fed barley made gains which were very satisfactory, but not quite as rapid as those fed corn. For 100 lbs. gain they required 50 lbs. more grain than the corn-fed pigs, but consumed 9 lbs. less tankage. With corn at 56 cents a bushel and tankage at $60 a ton, ground barley was actually worth about 95 per ct. as much as corn in these trials, so far as feed required for 100 lbs. gain was concerned. In 3 similar experiments[15] in which ground barley and tankage were

[14]Wis. Buls. 319, pp. 70–71; 323, pp. 8–10.

[15]Evvard, Iowa Station, information to the authors; Ferrin and Winchester, Kan. Cir. 89; Morrison and Bohstedt, Wis. Station, unpublished data.

compared with shelled corn and tankage for pigs on pasture, approximately the same results were secured on the average.

When pigs are self-fed barley and tankage, free choice, they will often over-eat on tankage. In fact, tho barley is much richer than corn in protein, pigs will frequently eat a larger proportion of tankage when fed barley than when given corn. This shows that despite the claims of some, pigs can not be expected to understand the composition of different feeds and eat just enough of protein-rich supplements to balance their ration. In the trials averaged in the previous table, experiments have not been included where pigs ate an excess of tankage when it was fed, free choice, or where the experimenters fed considerably more tankage than was needed to balance the ration. One of the strong points of barley as a feed is that it is richer than corn in protein. Where this fact is disregarded, full value is not secured from this grain.

Barley is a cool-weather crop, and that grown in the central corn belt and southward is often not so plump and heavy as that grown farther north. Perhaps due to this, in trials carried on at the Nebraska and Indiana Stations[16] the value of barley has not been so high compared with corn as in the trials at northern stations. Pigs fed ground barley (dry or soaked) and tankage in 6 trials at these stations gained 1.33 lbs. a day and required 480 lbs. barley and 36 lbs. tankage for 100 lbs. gain. Others fed shelled corn and tankage gained 1.63 lbs. and required 411 lbs. corn and 37 lbs. tankage for 100 lbs. gain. With corn at 56 cts. a bushel and tankage at $60 a ton, ground barley was worth only 86 per ct. as much as shelled corn in these trials.

Barley has the handicap that it must be ground or crushed for the best results in swine feeding, while this is not necessary with corn. Considering this fact, if plump, heavy barley, when ground, is worth 95 per ct. as much as shelled corn for swine, the same barley would be worth only about 85 per ct. as much as corn per pound, after deducting the cost of grinding.

In 4 comparisons by Thompson at the Oklahoma Station[17] pigs fed whole dry barley and tankage gained 1.04 lbs. a day and required 517 lbs. barley and 60 lbs. tankage for 100 lbs. gain. Others fed dry or moistened ground barley and tankage gained 1.34 lbs. a day, and needed only 431 lbs. barley and 47 lbs. tankage for 100 lbs. gain. Considering the saving in both grain and tankage, grinding increased the feeding value of the barley over 25 per ct. Similar results were secured in 2 trials by Loeffel at the Nebraska Station[18] in which whole dry barley was compared with ground soaked barley. In experiments at the Oregon Station[19] there was practically no difference in the value of barley which was coarsely ground and that which was finely ground or steamed and rolled.

[16]Loeffel, Nebr. Station, and Vestal, Ind. Station, information to the authors.
[17]Okla. Rpts. 28 and 29.
[18]Information to the authors.
[19]Fjeldsted and Potter, Ore. Bul. 165.

Soaking whole barley is usually a poor substitute for grinding it. In one trial by Loeffel at the Nebraska Station[20] it actually decreased the value of the barley, while in another there was a slight benefit from soaking the grain. In trials by Thompson at the Oklahoma Station,[21] soaking did not on the average increase the value of whole barley. In a trial by Morrison and Bohstedt at the Wisconsin Station[22] pigs fed soaked whole barley and tankage required over 40 per ct. more feed than others fed dry ground barley and tankage. Soaking ground barley does not generally increase its value materially.

Hulless barley resembles wheat in composition, and when ground, is about equal to corn or wheat in feeding value.

945. Wheat.—Wheat of good quality is nearly always too high in price compared with other grains to feed to stock, except in certain districts of the Northwest. (**215**) However, shrunken wheat that has been injured by drought or frost before maturity, is often an economical stock feed in the wheat growing districts, as it is unsuited for milling and sells at a low price. Such wheat is richer in protein than wheat of good milling quality and, if not too badly shrunken, may be equal in feeding value to sound wheat or barley.[23] The value of salvage wheat, which has been damaged in elevator fires, will depend on the extent of the injury by smoke and charring.

Good quality wheat, when ground, is worth fully as much as corn for swine feeding. This is shown by the following table that summarizes the results of 3 trials,[24] averaging 110 days, with a total of 46 pigs, in which ground wheat and ground corn were compared when fed with tankage:

Wheat vs. corn for fattening pigs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, Ground wheat, 6.2 lbs. Tankage, 0.64 lb	104	1.54	440
Lot II, Ground corn, 5.6 lbs. Tankage, 0.58 lb.....	98	1.37	454

The pigs fed wheat and tankage made slightly more rapid gains and required 3 per ct. less feed for 100 lbs. gain than those fed corn and tankage. In 9 other trials[25] in which wheat was compared with corn when fed without any supplement, it was likewise superior to corn. There is no appreciable advantage from mixing wheat and corn, either when these grains are fed alone or when fed with tankage.[26]

[20]Information to the authors.

[21]Okla. Rpts. 28 and 29.

[22]Wis. Bul. 319, pp. 67–68.

[23]Clark, Mont. Bul. 89; Day, Ont. Agr. Col. Rpt. 1908; Ferrin and Winchester, Kan. Cir. 89; Grisdale, Ottawa, Expt. Farms Rpt. 1908.

[24]Eastwood, Ohio Bul. 268; Weaver, Mo. Bul. 136.

[25]Kan. Bul. 53, and Rpt. Kan. Bd. Agr. 1894; Ky. Bul. 175; Mo. Bul. 136; Nebr. Bul. 75; S. D. Bul. 38; Wis. Rpts. 1894, 1895.

[26]Henry, Wis. Rpt. 1894; Weaver, Mo. Bul. 136.

Tho wheat is somewhat richer than corn in protein, nevertheless it requires the addition of a supplement to produce rapid and economical gains for pigs not on excellent pasture. As the proteins of wheat are unbalanced, like those of corn, the best results are secured with pigs in dry lot if there is included in the ration a protein-rich feed of animal origin, like the dairy by-products, tankage, or fish meal. Wheat should be ground coarsely or rolled, for swine, for thus preparing this grain increases the feeding value 16 to 22 per ct.[27] Soaking wheat is a poor substitute for grinding, as it makes but little saving over feeding the dry grain. Soaking ground wheat may increase its value slightly, but perhaps not enough to justify the trouble. Ground wheat, especially if too fine, tends to form a sticky mass in the pig's mouth. In such cases it may be advisable to feed it in the form of a thin slop.

946. Oats.—Oats are excellent as part of the ration for young pigs and for brood sows, for they are much higher in protein than is corn. (**223**) But they are too bulky and high in fiber to serve as the chief grain for fattening pigs, and moreover, are usually costly compared with other cereals. In a trial by Thompson at the Oklahoma Station[28] fattening pigs fed oats and tankage gained only 1.34 lbs. a day and required 633 lbs. oats and 35 lbs. tankage for 100 lbs. gain. Others fed corn and tankage gained 1.82 lbs. and required only about two-thirds as much feed for each 100 lbs. gain. Oats in this trial were actually worth only 59 per ct. as much as corn. In 2 trials by Dowell and Lattimer at the University of Alberta[29] pigs self-fed ground oats and tankage gained 0.34 lb. less a head daily than others self-fed ground barley and required considerably more feed for 100 lbs. gain. On the average oats fed as the only grain was worth about three-fourths as much per pound as barley.

When oats are considerably lower in price per ton than corn or barley, fattening pigs may be fed one-third oats and two-thirds of these more concentrated grains. Trials by Henry at the Wisconsin Station[30] and by Dowell and Lattimer at the University of Alberta, Canada,[31] show that a much larger proportion of oats is not desirable.

Where pigs are self-fed corn and tankage, free choice, it is sometimes recommended that oats be supplied in addition, to furnish greater variety. However, trials by Rice and Laible at the Illinois Station[32] show that there is usually no economy in this method. In fact oats would have to be worth less than one-half the price of corn per bushel to make the gains as cheap as on corn and tankage alone. As we shall see later, this ration of corn and tankage can be materially improved by adding certain other feeds. (**966**)

Oats should be ground or crushed for swine, as they masticate the

[27]Bliss, Lee, and Snyder, Nebr. Buls. 144, 147; Withycombe, Ore. Bul. 80.
[28]Okla. Rpt. 28, p. 28.
[29]Information to the authors.
[30]Wis. Rpt. 1889.
[31]Information to the authors.
[32]Information to the authors.

kernels less thoroly than corn. For very young pigs, ground oats with the hulls sifted out, or rolled oats, such as are used for human consumption, are excellent feeds, but they are usually too expensive to form much of the ration.

947. Emmer.—Emmer resembles oats closely in composition and feeding value, and should be fed in the same manner. (233) In trials by Burnett and Snyder at the Nebraska Station[33] it required 31 per ct. more ground emmer than ground corn for 100 lbs. gain when pigs were fed these grains with alfalfa hay. Good results were, however, secured with a mixture of half ground emmer and half ground corn. Emmer should always be ground for swine.

948. Rye.—In northern districts where corn is not the staple grain crop for swine, rye is sometimes an economical feed. (232) Tho it closely resembles wheat in composition, it is somewhat less palatable and is of slightly lower value than wheat or corn. Extensive trials have been carried on by Brown at the Michigan Station[34] to compare the value of rye, corn, and barley for swine feeding, in which the results summarized in the following table were secured. In each of 5 experiments the feeds indicated in the table were self-fed, free choice, to different lots of pigs, which averaged 70 to 143 lbs. in initial weight in the various trials. The grains were ground in all the trials.

Rye compared with corn and barley for swine

	Daily gain	Feed for 100 lbs. gain				
	Lbs.	Rye Lbs.	Barley Lbs.	Corn Lbs.	Tankage Lbs.	Total Lbs.
Rye and tankage	1.15	413	...	...	42	456
Corn and tankage	1.47	...	...	395	40	435
Barley and tankage	1.30	...	444	...	28	472
Rye, barley, and tankage	1.21	178	257	...	32	467
Rye, barley, corn, and tankage	1.39	139	53	239	30	462

It will be observed that the pigs self-fed corn and tankage made the largest gains and required the least feed for 100 lbs. gain. However, the results on rye were satisfactory. Considering both the grain and the tankage required for 100 lbs. gain, ground rye was worth about 94 per ct. as much per ton as ground corn. There was a slightly greater difference in the value of rye and corn in a trial at the Ohio Station,[35] while in a trial at the Kansas Station[36] ground rye was practically equal to ground corn.

In the Michigan trials and likewise in a trial at the Wyoming Station[37] ground rye was slightly more valuable than ground barley. On the other

[33]Nebr. Bul. 99.
[34]Information to the authors.
[35]Eastwood, Ohio Bul. 268.
[36]Ferrin and Winchester, Kan. Cir. 89.
[37]Faville, Wyo. Bul. 114.

EXPERIMENTS PROVE HOGGING DOWN CORN TO BE ECONOMICAL

In various trials pigs hogging down corn in which rape or other supplemental crops have been grown have made larger and cheaper gains than those fed ear corn in a dry lot.

A CARLOAD OF BACON PIGS AT THE STOCK YARDS

The Large Yorkshires, shown in the illustration, and the Tamworths have been specially developed for the production of high-quality bacon. Note the length of body and leg of these pigs. See Pages 618-20.

PIGS MAKE CHEAPER GAINS UNDER SUCH CONDITIONS

Pigs fed well-balanced rations on good pasture and in sanitary quarters can be expected to make economical gains.

UNDER THESE CONDITIONS PROFITS SHOULD NOT BE EXPECTED

Pigs which have no pasture and are in filthy, unsanitary quarters make expensive gains. Many become runts or die because of disease or infection with worms.

hand trials by the Oregon and Nebraska Stations[38] show that rye is worth 4 to 8 per ct. less than wheat for fattening pigs.

It is often recommended that rye be mixed with corn or other grains to increase the palatability, and in the Michigan trials pigs self-fed barley or both barley and corn, in addition to rye and tankage, made slightly larger gains, but they required fully as much feed for 100 lbs. gain as those fed rye and tankage alone. Brown also found that there was little or no advantage in adding middlings to a ration of rye and tankage. The poor results which are sometimes secured with rye are quite possibly due to the use of rye contaminated with ergot. Especial care should be taken not to feed such grain to pregnant sows, or abortion may result. (396)

Rye should be ground coarsely or rolled for swine. Trials by Hays at the Delaware Station[39] show that the same general conclusions concerning grinding and soaking hold for this grain as for wheat. Also, just as in the case of wheat, a supplement should be added to balance the ration, except perhaps for pigs on pasture.

949. Kafir and other grain sorghums.—Thruout the western plains states the grain sorghums are of great importance for pork production, for in many districts they are the cheapest feeds available. These grains are quite similar in composition to corn, except that they average lower in fat and slightly higher in crude protein, and furnish slightly less total digestible nutrients. Like corn, the grain sorghums should accordingly always be supplemented with protein-rich feeds. Also, just as in the case of corn, the proteins of these grains are unbalanced in composition. Therefore the best results for pigs not on pasture are secured when supplements of animal origin, like dairy or meat by-products, are included in the ration. If none of these feeds is available or economical, then it is probably best to see that the pigs are supplied good alfalfa hay or hay from other legumes in addition to such supplements as linseed meal and wheat middlings.

As seeds of the grain sorghums are hard and relatively small, the grain should be ground for swine. Where this is not possible, it is best to feed the sorghums on the head rather than to use the threshed grain, for the pigs will then be forced to chew the kernels more thoroly. This is shown in a trial by Cochel at the Kansas Station[40] in which pigs fed ground kafir with shorts, tankage, and alfalfa hay gained 1.40 lbs. a head daily, and required 534 lbs. concentrates for 100 lbs. gain. Others fed whole threshed kafir instead of the ground grain gained only 1.15 lbs. and required 34 per ct. more concentrates for each 100 lbs. gain. On kafir heads, pigs made slightly smaller gains than on ground kafir, but the gains were as cheap as on the ground kafir grain.

Kafir, the most common of the grain sorghums, has been compared

[38]Fjeldsted and Potter, Ore. Bul. 165; Snyder, Nebr. Bul. 147.

[39]Del. Bul. 124.

[40]Kansas Industrialist, May 1, 1915.

with corn in 7 trials,[41] which are summarized in the following table. In each trial these grains were ground and were properly balanced by tankage, tankage and shorts, or alfalfa hay. The pigs averaged 122 lbs. in weight when the trials began and they were fed for an average of 63 days.

Kafir vs. corn for fattening pigs

	Feed for 100 lbs. gain		
	Kafir or corn Lbs.	Tankage Lbs.	Shorts or hay Lbs.
Lot I, Fed ground kafir and supplements	402	25	49
Lot II, Fed ground corn and supplements	370	24	44

The daily gain was not reported in two of the trials, but in the others it was nearly as rapid on kafir as on corn. It will be noted that the pigs fed ground kafir required 32 lbs. more grain, 1 lb. more tankage, and 5 lbs. more shorts or alfalfa hay for 100 lbs. gain than those fed ground corn. With feeds at usual prices ground kafir was worth about 90 per ct. as much as ground corn in these trials. In addition, there is the fact that the grain sorghums should be ground for swine feeding, while this is not necessary with corn. (**237**)

950. Milo; feterita.—*Milo* is raised extensively in the drier portions of the grain sorghum belt, as it matures earlier than kafir. In 5 trials at the Kansas Station,[42] ground milo was worth 5 per ct. more than ground kafir for fattening pigs when both were properly balanced with tankage, alfalfa hay, or tankage and shorts. (**238**)

Feterita, which is also earlier in maturity than kafir, has proven fully equal to milo for swine feeding in trials at the Kansas Station.[43] In a trial by Dvorachek and Sandhouse at the Arkansas Station[44] ground feterita was slightly superior to ground kafir. (**239**)

951. Kaoliang; sorghum seed; darso.—*Kaoliang*, a very early maturing variety of grain sorghum suited to the northern plains section, is apparently less valuable than kafir, milo, or feterita for swine feeding. In a trial by Wilson at the South Dakota Station[45] ground kaoliang was worth only about four-fifths as much as ground corn per 100 lbs., either when fed with alfalfa hay, or when the grains were fed without any supplement. (**240**)

Seed from the sweet sorghums, or sorghos, is not as palatable to swine as the seeds of the grain sorghums and has a lower feeding value. In 3 trials at the Kansas Station[46] pigs fed ground sorghum seed with protein-

[41]Dvorachek and Sandhouse, Ark. Cir. 34; Cochel, Kan. Industrialist, May 1, 1915; Ferrin and Winchester, Kan. Cir. 89; Malone, Okla. Bul. 120; Waters et al., Kan. Bul. 192.

[42]Cochel, Kansas Industrialist, May 1, 1915; Ferrin and Winchester, Kan. Cir. 89; Waters et al., Kan. Bul. 192.

[43]Cochel, Kansas Industrialist, May 1, 1915; Ferrin and Winchester, Kan. Cir. 89.

[44]Ark. Cir. 34.

[45]S. D. Bul. 157.

[46]Waters, Kinzer, et al., Kan. Bul. 192.

rich supplements gained 1.20 lbs. daily, compared with 1.60 lbs. for pigs fed ground corn in place of sorghum and 1.49 lbs. for others fed ground kafir. In these trials ground sorghum was worth only 63 per ct. as much per 100 lbs. as ground corn and only 70 per ct. as much as ground kafir. In a trial at the Oklahoma Station[47] ground sorghum seed was worth 78 per ct. as much as corn, while in a trial at the Nebraska Station[48] ground sorghum seed was worth only 68 per ct. as much as ground corn when fed with alfalfa hay. The pigs gained only 1.15 lbs. a day on sorghum, while those fed corn gained 1.69 lbs. On a mixture of half sorghum and half corn the gains were more rapid, but the value of the sorghum per 100 lbs. compared with corn was about the same. (**241**)

Darso, an early-maturing variety of the sweet sorghums, produced practically as rapid gains as corn or kafir in a trial by Malone at the Oklahoma Station[49] in which tankage was fed as the supplement. However, the pigs fed darso required considerably more feed for 100 lbs. gain, and hence the darso was actually worth only about three-fourths as much as ground corn per 100 lbs. In a later experiment darso was worth 95 per ct. as much as corn. (**241**)

952. Millet.—Proso, or hog millet, which is sometimes raised for grain in the northern plains states, is a satisfactory feed for swine when ground, but ranks somewhat below ground barley in feeding value.[50] (**243**) As millet is a carbonaceous grain, it should be supplemented by a suitable protein-rich concentrate.

953. Buckwheat.—Buckwheat is rarely used for stock feeding and is less valuable for this purpose than corn, owing to the woody hulls. In Canadian trials[51] buckwheat has been slightly inferior to wheat or wheat middlings for fattening pigs. Buckwheat tends to produce poor quality bacon when it forms a large part of the ration,[52] and it may also cause skin eruptions on the pigs. (**244**)

954. Screenings; weed seeds.—Only the heavier grades of screenings, containing little chaff and consisting of broken or shrunken wheat, weed seeds, etc., are at all suitable for swine. Screenings should always be ground for swine and had best be mixed with more palatable feeds. At theWisconsin Station[53] Henry found that pigs refused to eat any large quantity of raw pigeon-grass seed meal, but they ate it readily after it was cooked. A mixture of 2 parts of the cooked meal and 1 part of corn meal gave as good results as corn meal. In a Manitoba trial[54] 100 lbs. of

[47]Okla. Rpt. 30, p. 16.
[48]Snyder, Nebr. Bul. 124.
[49]Okla. Bul. 120; Okla. Rpt. 30, p. 15.
[50]Wilson and Skinner, S. D. Bul. 83.
[51]Ottawa Expt. Farms Rpts. 1894, 1901.
[52]Grisdale, Ottawa, Expt. Farms, Bul. 51.
[53]Wis. Rpt. 1894.
[54]Ottawa Expt. Farms Rpt. 1902.

lambs' quarter seed screened from wheat equalled 60 lbs. of mixed grain for pigs, when fed as only one-fifth the ration.

955. Miscellaneous carbonaceous feeds; mixed feeds.—*Rough rice*, when ground, may be used as a substitute for other grain when it is cheap in price.[55] Owing to the hulls, it is nearly as high as oats in fiber and hence worth considerably less per pound than corn. (**234**)

Rice polish has proven to be worth even more than corn for fattening pigs. In 4 trials by Dvorachek at the Arkansas Station[56] 100 lbs. of rice polish was equal to 125 lbs. of ground corn, when both were properly supplemented with tankage, skim milk, or buttermilk. Rice polish did not, however, prove as palatable as corn, especially toward the close of the fattening period, and when large quantities were fed it tended to cause scours unless it was thoroly soaked for 12 to 24 hours before feeding or unless lime water was given the pigs.

Rice bran is often an economical feed for swine in the rice growing districts of the South, but feeding too large a proportion of this feed produces soft pork, which is discounted by the packers. From trials at the Texas Station[57] it appears that rice bran may be fed with equal parts of corn grain and sorghum, and 10 per ct. tankage without causing soft pork, and in all probability the rice bran may even form 60 per ct. of the ration without injuring the pork. In trials at the Arkansas Station[58] rice bran was worth about 90 per ct. as much as ground corn, while in a Texas trial[59] it was worth only about three-fourths as much per 100 lbs. as corn.

Molasses, either beet or cane, is used less commonly for feeding swine than for cattle, horses, or sheep. When cheaper than corn or other grain, molasses may be substituted for a part of the grain in the ration of swine. (**277, 280**) When fed as a partial substitute for grain or other concentrates, cane molasses was worth about as much, pound for pound, as ground barley or wheat mixed feed in trials at the Oregon Station,[60] but in an experiment at the Mississippi Station[61] it took 1.8 to 1.9 lbs. molasses to equal 1 lb. of corn. In a trial at the New Jersey Station[62] with brood sows satisfactory results were secured, when 2.3 lbs. cane molasses was substituted for part of the corn in a ration of corn, tankage, alfalfa hay, and mangels, but the molasses was worth less per pound than corn. The outcome was unsatisfactory when molasses was substituted for all the corn in the ration.

Beet molasses is apt to cause scours in pigs unless they are started on it very gradually and only limited amounts are fed.[63]

[55]Jordan and Kidder, La. Bul. 179.
[56]Ark. Bul. 128.
[57]Burk, Tex. Bul. 224; Williams and McConnell, Tex. Bul. 286.
[58]Dvorachek, Ark. Bul. 128.
[59]Williams and McConnell, Tex. Bul. 286.
[60]Fjeldsted and Potter, Ore. Bul. 165.
[61]Griswold, information to the authors.
[62]Hunter, N. J. Rpt. 1917, pp. 111–4. [63]N. Y. (Cornell) Bul. 199.

Mixed feeds of many different types are being manufactured for swine. Some are intended as complete rations, while others are protein-rich feeds to be used as substitutes for such feeds as tankage or dairy by-products, and still others are relatively low in protein. In extensive experiments by Evvard and colleagues at the Iowa Station,[64] and also in trials at the Indiana and the Washington Stations,[65] the gains have in nearly all cases been cheaper on well-balanced rations made up of farm grains and common protein-rich supplements, than where commercial mixed feeds were fed. From these experiments we may conclude that an intelligent farmer who is capable of balancing rations properly for his stock will usually find such mixed swine feeds economical only when they actually furnish nutrients as cheap or cheaper than rations made up of farm grains and protein-rich supplements. Mixed feeds for swine should be low in fiber, as these animals are not suited to utilize much of such low grade feeds as reground oat feed (chiefly oat hulls) or chaffy grain screenings. (288)

956. Garbage.—Until the discovery of methods of vaccination against hog cholera, most attempts to feed swine household garbage on a large scale were unsuccessful, due to heavy losses from this disease. Now, however, the garbage from a large number of cities is fed to swine. Indeed in 1918, 345 cities in the United States of over 10,000 inhabitants and having a total population of 11,000,000 were thus disposing of their garbage. In most cases the garbage is fed by contractors who purchase the collected garbage from the cities or else collect it themselves under rigid rules. Garbage feeding is a highly specialized phase of pork production and cannot be here treated at length, but the following general points are of special interest:[66]

Garbage varies greatly in composition and feeding value, but on an average and allowing for normal losses of hogs by death, a ton of municipal garbage may be expected to produce 40 lbs. of marketable live weight of hog. Garbage of excellent quality, such as that from large hotels and restaurants, may be twice as valuable as this.

The garbage must be collected with reasonable frequency and be free from tin cans, soap, broken glass, and other undesirable or injurious foreign articles. The public should be kept informed that the garbage is being fed, so they will not put such material in the garbage. Usually it is best for the cities to make the collections and then dispose of the garbage to individuals or corporations on a contract basis, unless the city operates its own hog-feeding farm. Long-time contracts are likely to be most satisfactory, for they tend toward a better class of equipment and more sanitary conditions.

The pigs to be fed may be bought as feeders or may be raised. Methods of feeding, handling, housing, and care may differ considerably

[64]Information to the authors.

[65]Skinner and Starr, Ind. Bul. 219; Hislop, Wash. Rpt. 1916, pp. 8–9.

[66]Chiefly from Ashbrook and Wilson, U. S. D. A. Farmers' Bul. 1133.

so long as the essentials of sanitation and hog comfort are observed. Equipment for feeding should be adapted to the type of garbage available and to local conditions, climate, and transportation.

Raw garbage generally is better for hogs than cooked garbage. Frozen garbage, however, should be thawed before feeding. As a rule the use of grain as a supplementary feed is not an economical practice, but grain may be used to advantage when the supply of garbage is temporarily short. Hogs to be fed garbage should be immunized against cholera, preferably by the double treatment. Thoro immunization is very important because of raw pork scraps frequently deposited in garbage cans. Garbage-fed hogs show no greater susceptibility to tuberculosis, pneumonia, or kindred diseases than grain-fed animals. The pork is as good in quality as that produced on other feeds, and average garbage-fed hogs sell at practically the same prices as average grain-fed animals.

II. Protein-rich Concentrates

957. Dairy by-products.—Skim milk and buttermilk are rich in protein, and, most fortunately, the protein is rich in the very amino acids, or "protein building stones," which are not plentiful in the grains. These dairy by-products are also rich in mineral matter, especially in calcium and phosphorus, which are the chief minerals in the skeleton. These qualities make skim milk and buttermilk ideal supplements to the farm grains for pigs, which need rations rich in protein, lime, and phosphoric acid, because they are growing rapidly. Indeed, it is well known that when skim milk or buttermilk is used as a supplement to corn or other grains for growing, fattening pigs, usually the gains will even be slightly larger than when such an excellent protein-rich feed as tankage or meat meal is used to balance the ration. These dairy by-products are also just as excellent for brood sows, which likewise need plenty of protein and a liberal supply of calcium and phosphorus. Skim milk is so useful for pigs that many breeders of pure-bred hogs keep a dairy herd in order to have the by-products for their swine, especially for the young pigs.

Due to the high efficiency of the milk proteins as supplements to the grains and also to the richness of milk in calcium, skim milk and buttermilk are far superior to such feeds as linseed meal, wheat middlings, gluten feed, or corn germ meal, when used as the only supplement for swine not on pasture, and especially for young pigs. (**937, 969, 980**)

Most of the fat-soluble vitamine has been removed from separator skim milk, buttermilk, and whey. Experiments by Morrison, Bohstedt, and Fargo at the Wisconsin Station, which have been mentioned previously, show that, because of this, poor results may be secured if these dairy by-products are fed with other feeds low in this vitamine, as is white corn. (**939**) Such a deficiency of fat-soluble vitamine is most apt to affect young pigs. Apparently, such trouble may be prevented by adding 5 per ct. of good alfalfa hay or other legume hay to the ration.

It has been emphasized before that skim milk, buttermilk, or whey should always be pasteurized at the creamery or cheese factory before being returned to the farm, in order to prevent the spread of tuberculosis and other diseases. Swine are especially susceptible to tuberculosis and may contract the disease not only from infected milk, but as Kennedy and Dinsmore found at the Iowa Station,[67] by following tuberculous cattle to work over the droppings. (269)

958. Skim milk.—Many trials have been carried on by the experiment stations to determine the feeding value of skim milk, but in most of the early trials balanced rations of grain and skim milk were compared with unbalanced and inefficient rations of grain alone. This is obviously not a fair basis for determining the value of skim milk, for no progressive farmer now feeds his pigs such an inefficient ration as grain alone when they are not on pasture. To find the actual feeding value of skim milk we should compare it with the best common commercial substitute, which is tankage, or meat meal. Furthermore, just enough skim milk and just enough tankage should be fed to make well-balanced rations, or the comparison will be unfair to one of the feeds. The value of skim milk as a supplement to corn for pigs not on pasture has been directly compared with that of tankage in 12 trials[68] at 4 different stations. In each of these trials, which are summarized in the following table, one lot of pigs was fed a ration of skim milk and corn (yellow corn in nearly all cases) in the proper proportions to make a well-balanced ration, and another lot was fed proper proportions of tankage and corn. These comparisons therefore furnish an accurate measure of the actual feeding value of skim milk for growing and fattening pigs. The trials included a total of 138 pigs, averaging 75 lbs. in weight at the start, fed for periods averaging 97 days.

Skim milk vs. tankage as supplement to corn for fattening pigs

Average ration	Daily gain	Feed for 100 lbs. gain		
		Corn	Skim milk	Tankage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, fed skim milk				
Skim milk, 7.1 lbs.				
Corn, 4.6 lbs.	1 36	346	535	..
Lot II, fed tankage				
Tankage, 0.47 lb.				
Corn, 4.9 lbs.	1.24	404	...	39

The pigs fed skim milk and corn in these extensive trials gained 1.36 lbs. a head daily, which was 0.12 lb. more than those fed tankage and corn. On skim milk and corn there were required only 346 lbs. corn and 535 lbs. skim milk for 100 lbs. gain, while the pigs on tankage and corn consumed 404 lbs. corn and 39 lbs. tankage for each 100 lbs. gain. By

[67] Iowa Bul. 107.

[68] Average of 6 trials by Morrison, Bohstedt, and Fargo, Wis. Station (unpublished data); 4 trials by Robison, Ohio Buls. 316 and 349; 1 trial by Dvorachek, Ark. Cir. 38; and 1 by Skinner and Cochel, Ind. Bul. 137.

computation it will be found that in these trials each 100 lbs. of skim milk saved 10.86 lbs. corn and 7.29 lbs. tankage, without giving any credit for the more rapid gains produced by feeding skim milk. The high value of the dry matter in skim milk is shown by the fact that 100 lbs. of skim milk, containing only 9.9 lbs. dry matter, replaced 15.7 lbs. of dry matter in corn and tankage. As is pointed out later, skim milk would have had a lower value than this if more had been fed than was needed to balance the ration. (**960**) As a supplement to other grains, skim milk has about the same value as when fed with corn.

For pigs before and soon after weaning skim milk is best if fed fresh, tho even for young pigs skim milk which has soured under sanitary conditions is satisfactory. However, if sour milk is to be used, it should always be fed sour. Feeding the milk sweet at one feeding and sour at the next is apt to cause scours.

959. Money value of skim milk.—From the fact that 100 lbs. of skim milk is equal in feeding value to 10.86 lbs. corn and 7.29 lbs. tankage, its money value with corn and tankage at various prices may be readily computed. As is shown later (**962**), undiluted buttermilk equals skim milk in feeding value. For convenience, the money value of 100 lbs. of skim milk or buttermilk with corn and tankage at various prices is shown in the following table. It should be borne clearly in mind that these values will be secured only when no more milk is fed than is needed to balance the ration. The value of these dairy by-products when larger amounts are fed is discussed later. (**960**)

Money value of skim milk or buttermilk per 100 lbs., for pigs

	Price of corn per bushel				
	$.40	$.56	$.70	$.85	$1.00
Value of 100 lbs. skim milk or buttermilk	Cents	Cents	Cents	Cents	Cents
With tankage at $40 a ton	22	25	..	..	..
With tankage at $50 a ton	26	29	32	..	..
With tankage at $60 a ton	30	33	35	38	..
With tankage at $70 a ton	33	36	39	42	45
With tankage at $80 a ton	..	40	43	46	48
With tankage at $100 a ton	..	..	50	53	56

This table measures, in a general way, the value of skim milk when properly combined with grain for fattening pigs. Those familiar with this feeding stuff and its worth for bone and muscle building know that in many cases, especially for young pigs, its value is much higher.

The table shows clearly that the actual value of skim milk and buttermilk is influenced by the price of both corn and tankage. As a rule, when corn is high in price, tankage will also be expensive. Therefore blanks are left in the table for price combinations which are practically never met, such as corn at $1.00 per bushel and tankage at $60 or less a ton. It will be noted that with corn and tankage at any usual prices, 100 lbs.

of skim milk or buttermilk is worth about as much or even more than one-half a bushel of corn, when only enough skim milk is fed to balance the ration. The results of these recent experiments therefore agree roughly with the rule proposed many years ago by Gurler, which was: "The value of 100 lbs. of skim milk when fed along with corn to fattening hogs is half the market price of corn per bushel." As is shown in the table, however, the actual money value of skim milk varies not only with the price of corn, but also with the price of tankage or other available protein-rich feeds, for skim milk saves both corn and protein-rich supplement.

960. Proper proportion of skim milk or buttermilk to grain.—Skim milk and buttermilk are too watery and also too rich in protein to produce economical gains when fed alone. They should therefore always be fed with the cereals or such carbonaceous concentrates as hominy feed or corn feed meal. The proportion of skim milk or buttermilk to be fed with corn or other grain will depend first on the age of the pigs and next on the relative price of the feeds. After sufficient milk has been supplied to balance the ration, any addition will not increase the rate of gain materially and may even lower it if too much is fed.

Just after weaning, 4 to 6 lbs. of skim milk or buttermilk to each pound of corn will be sufficient to make maximum gains with pigs in a dry lot. As they grow older the proportion of skim milk or buttermilk needed to balance the ration decreases as follows: Pigs weighing 50 to 100 lbs., 2.5 to 3 lbs. milk to 1 lb. corn; pigs weighing 100 to 150 lbs., 2 to 2.5 lbs. milk to 1 lb. corn; pigs weighing 150 to 200 lbs., 1.5 to 2.0 lbs. per pound of corn; and pigs weighing over 200 lbs., only 1.0 to 1.5 lbs. of milk for each pound of corn. Where barley or wheat is fed in place of corn, only about half to two-thirds as much milk is needed for each pound of grain as with corn.

Pigs fed corn on good pasture will need only about half as much milk for each pound of grain. If the above amounts of milk are available, there is no use of adding any other protein-rich feed. But if sufficient skim milk or buttermilk is not on hand, it will pay to feed a small amount of some other supplement, like tankage, linseed meal, or wheat middlings, to balance the ration properly.

Pigs on the one hand need a large proportion of skim milk to each pound of corn when they are young, and on the other hand consume more grain per head daily as they grow older. Therefore, the actual number of pounds of skim milk needed per head daily to balance the ration does not vary so widely for pigs full fed on corn. Generally 6 to 10 lbs. of skim milk per head daily will be enough to balance the ration properly for pigs not on pasture which are self-fed corn or hand-fed all they will eat. On pasture they will need only about half as much skim milk. Due to the high efficiency of the milk proteins as supplements to the cereal grains, pigs fed grain and skim milk or buttermilk do not require quite as much protein as is generally advised in the feeding standards.

Therefore in computing balanced rations for pigs of various weights with skim milk or buttermilk as the supplement, the minimum amounts of digestible crude protein recommended in the Morrison feeding standards can safely be taken as a guide. (Appendix Table V.)

If an abundance of skim milk or buttermilk is available on the farm, a greater amount than stated previously may be economically fed, but this excess amount over what the pigs really need to balance their rations will be worth only about half as much or less. After the pig is fed enough protein to balance his ration, he uses the excess merely to make fat instead of lean meat, and consequently full value is not secured from the protein.

The lessened value of skim milk per 100 lbs. when more is fed than is needed to balance the ration is clearly shown in trials by Henry at the Wisconsin Station[69] in which a total of 88 pigs, usually weighing 100 lbs. or over, were fed different proportions of skim milk and corn meal. When 1 to 3 lbs. of skim milk was fed to 1 lb. of corn, 327 lbs. of milk saved 100 lbs. of corn. However, with 3 to 5 lbs. of milk for each pound of corn, it required 446 lbs. of milk to save 100 lbs. of corn; and with 5 to 7 lbs. of milk per pound of corn, it took 574 lbs. of skim milk to save 100 lbs. of corn. In 2 recent trials at the Ohio Station[70] Robison fed different lots of pigs from weights of 33 to 45 lbs. up to market weights on various proportions of skim milk and corn in comparison with a lot fed corn and tankage in proper amounts. With corn at 56 cents a bushel and tankage at $60 a ton, skim milk was worth 51 cents per 100 lbs. when 1 lb. of skim milk was fed with 1 lb. of corn. When 3 lbs. of milk were fed per pound of corn, the value of 100 lbs. of skim milk was reduced to 30 cents, and when they were allowed to drink all the skim milk they would take in addition to a full feed of corn, each 100 lbs. of the milk was worth only 21 cents.

961. Whole milk.—Because of the high value of butter fat for human food, it is not profitable to feed whole milk to pigs, except perhaps in the case of orphan pigs raised by hand. (**1038**) Indeed, it was found in a trial by Linfield at the Montana Station[71] that whole milk is worth only about twice as much per 100 lbs. as skim milk for pigs. Scheven[72] found that when whole cow's milk was fed to 12-weeks-old pigs, from 900 to 1,620 lbs. was required to produce 100 lbs. of gain, the average being 1,253 lbs. The trials of Beach at the Connecticut (Storrs) Station[73] show that cow's milk rich in fat is not as good as milk lower in fat for young pigs, as it is apt to cause digestive disturbances on account of the high fat content. (**117**)

962. Buttermilk; buttermilk products.—Buttermilk which has not been diluted by adding the churn washings has practically the same chemical composition as skim milk, and is equal to it in feeding value. This is

[69] Wis. Rpt. 1895.
[70] Ohio Bul. 316.
[71] Utah Bul. 94.
[72] Martiny, Die Milch.
[73] Conn. (Storrs) Bul. 31.

shown by trials at the Massachusetts and South Dakota Stations,[74] in which pigs fed buttermilk and corn made as large gains and required no more feed for 100 lbs. gain than others fed skim milk and corn. It is essential that buttermilk be fed under sanitary conditions. If allowed to spoil in a filthy tank it is a poor feed, for it may cause severe scours. Horlacher found at the Kentucky Station[75] that buttermilk 2 days old or more was a satisfactory feed, if kept in sanitary containers. Buttermilk should always be pasteurized thoroly before being returned from the creamery to the farm, else tuberculosis and other diseases may be spread widely. (**269**)

Semi-solid buttermilk is produced by evaporating buttermilk in a partial vacuum until it is condensed to one-third or one-fourth the original volume. This product is of paste-like consistency and is shipped in barrels. Owing to the lactic acid it contains, it will keep after the barrel is opened, if a piece of oil cloth or thick paper is pressed down on the exposed surface, or if the surface is covered with an inch of water.

Semi-solid buttermilk contains only 13 to 15 per ct. crude protein and about the same amount of nitrogen-free extract, which consists of lactic acid and lactose (milk sugar). It contains only about one-fourth as much crude protein as high grade tankage, and is a relatively watery feed, as over 60 per ct. of it is water. Yet it commonly costs nearly as much per ton as tankage. Semi-solid buttermilk is therefore a very expensive feed, compared with tankage and other protein-rich feeds.

Some breeders who lack a supply of skim milk, buttermilk, or whey add a small amount of this product to the rations of swine being fitted for show or of young pigs. However, semi-solid buttermilk is too high in price, considering the nutrients it actually contains, to be an economical substitute for tankage in fattening pigs for the market, either in dry lot or on pasture. The following table summarizes the results of 4 trials,[76] with pigs averaging 114 lbs. in weight at the start, in which corn and semi-solid buttermilk has been compared with corn and tankage for pigs in dry lot and for an equal number of similar trials[77] with pigs on pasture.

Semi-solid buttermilk vs. tankage for pigs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain: Corn Lbs.	Buttermilk Lbs.	Tankage Lbs.
Pigs in dry lot				
Lot I, S.-s. buttermilk, 0.81 lb. Corn 6.6 lbs.	1.53	431	57	..
Lot II, Tankage, 0.49 lb. Corn, 6.1 lbs.....	1.54	396	..	33
Pigs on pasture				
Lot I, S.-s. buttermilk, 1.4 lbs. Corn, 6.1 lbs.	1.84	324	79	..
Lot II, Tankage, 0.37 lb. Corn, 6.2 lbs.	1.78	333	..	21

[74]Goesmann, Mass. Rpts. 1884, 1885; Wilson, S. D. Bul. 136.

[75]Poland China Jour., Feb. 10, 1922.

[76]Average of 2 trials by Gramlich and Loeffel (Nebr. Bul. 176 and information to the authors); 1 trial by McCampbell (Kan. Cir. 78); and 1 trial by Vestal, Ind. Station (Information to the authors).

[77]Average of 2 trials by Gramlich (Nebr. Bul. 176), and 2 by Grimes (Penn. Bul. 168).

There was practically no difference in rate of gain between the pigs fed semi-solid buttermilk and those fed tankage, either in dry lot or on pasture. With corn at 56 cents a bushel and tankage at $60 a ton, semi-solid buttermilk was actually worth only $20.34 a ton in these trials, while the price was nearly as high as that of tankage. In each of the 8 trials the ration of tankage and corn produced materially cheaper gains than semi-solid buttermilk.

Semi-solid buttermilk has had a higher value per ton where a relatively small amount has been added to a ration already quite well balanced. In 5 trials[78] semi-solid buttermilk has been added to rations of corn and tankage, or of corn, tankage, and shorts, or else has been substituted for tankage in a ration of grain, tankage, and either shorts or alfalfa hay. The pigs fed semi-solid buttermilk in these trials received 1.0 lb. a head daily and gained 1.65 lbs., compared with 1.47 lbs. for those receiving none of this feed. On the average, however, semi-solid buttermilk was worth only about two-thirds as much as tankage, while its cost was nearly as high as that of tankage. In 3 trials by Ferrin and McCarty at the Minnesota Station,[79] semi-solid buttermilk proved an uneconomical feed for pigs when rations of shelled corn, semi-solid buttermilk, and red dog flour, with or without linseed meal in addition, were compared with a ration of corn, tankage, red dog flour, and linseed meal.

Dried buttermilk is an excellent protein-rich feed for young pigs, but its high price makes it uneconomical compared with other supplements usually available. Tho it contains less than 40 per ct. protein, the cost per ton is usually about twice that of tankage containing 60 per ct. protein. In a trial at the Iowa Station[80] Evvard found that, pound for pound, dried buttermilk was actually worth less than tankage as a supplement to corn for fattening pigs.

963. Whey.—Whey is relatively low in protein, as the casein of the milk is removed in cheesemaking. Indeed there is but 0.8 lb. protein in 100 lbs. of whey and the nutritive ratio is 1 :6.8. Owing to this low content of protein, until recently it was not thot that whey had any value as a supplement to the cereal grains. However, surprising results have been secured in feeding trials by Morrison and Bohstedt at the Wisconsin Station[81] in which well-grown pigs weighing 125 to 150 lbs. have been fattened on only barley and skimmed whey. In 2 trials pigs self-fed ground barley and given in addition all the whey they would drink gained 2.22 lbs. a head daily, eating 7.8 lbs. barley a day and drinking 18.4 lbs. whey. They required only 353 lbs. barley and 854 lbs. whey for 100 lbs. gain. Pigs self-fed barley and tankage gained on the average only 1.64 lbs. daily in these trials, and required 450 lbs. barley and

[78]Evvard and Culbertson, Iowa Station (Information to the authors); Ferrin and Winchester (Kan. Cir. 78); Gramlich and Loeffel (Nebr. Bul. 175 and information to the authors); Weaver, Mo. Station (Information to the authors).

[79]Information to the authors.

[80]Information to the authors.

[81]Wis. Buls. 319, pp. 70–71; 323, pp. 8–10.

23 lbs. tankage for 100 lbs. gain. These excellent gains were secured on the ration of only whey and barley in spite of the fact that it had a nutritive ratio of 1:7.4, thus furnishing considerably less protein than is usually recommended for growing and fattening pigs. These results are apparently due to the fact that while whey is low in protein, the protein it does contain, which is chiefly milk albumin, is of excellent quality to serve as a supplement to the proteins of the cereals. (268)

Other trials at the same station have shown that for younger pigs some protein-rich feed, such as linseed meal or wheat middlings, should be added to barley and whey to balance the ration more completely. With corn and whey, a supplement should be fed even to pigs over 150 lbs. in weight, for corn contains considerably less protein than barley. An important fact brought out in these trials is that if pigs are given what whey they will drink there is no further need, even for young pigs in dry lot, of supplying protein-rich feeds of animal origin. Entirely satisfactory results are secured when the ration is balanced by the cheaper protein-rich concentrates of plant origin, like linseed meal and wheat middlings.

In these trials skimmed whey was worth about one-half as much per 100 lbs. as skim milk. This means that 100 lbs. of skimmed whey is worth about one-fourth as much as a bushel of corn. Unskimmed whey from American or cheddar cheese factories, which contains about 0.3 per ct. fat, will be worth a trifle more, and unskimmed whey from Swiss factories, which may contain 0.8 to 1.0 per ct. fat, will have a materially higher value than skimmed whey. Whey should always be pasteurized at the factory to prevent the spread of disease and should be fed under sanitary conditions. Whey soured in clean containers[82] is as valuable as sweet whey, but that from a putrid whey tank is a dangerous feed.

964. Tankage or meat meal.—The value of tankage or meat meal as a supplement to corn or other carbonaceous concentrates has been demonstrated in trials at many stations and by experience on many farms. Rich in protein which is well-balanced in composition (118) and likewise high in calcium and phosphorus, tankage is equalled only by skim milk, buttermilk, and fish meal in producing thrifty growth and large gains. Not only is tankage an excellent feed for pigs, but it also has the same rank for feeding breeding stock.

Tankage is one of the best single supplements for the grains, but for all pigs not on pasture, and especially young pigs, decidedly better results are secured when certain other supplements are added to the ration. It is pointed out elsewhere that less rapid and less economical gains are generally made on grain and tankage alone than when there are added to the ration one or more of the following feeds—linseed meal, wheat middlings, corn germ meal, or alfalfa hay. (966)

Since tankage or meat meal for stock feeding is thoroly cooked under pressure at a high temperature, there is no danger of spreading disease

[82]Day, Ontario Agr. Col. Rpt. 1897.

by its use. (270) Commonly the terms "tankage" and "meat meal" are used for the same product.

The results of trials in which well-proportioned rations of corn and tankage have been compared with corn alone for pigs not on pasture, have been given on previous pages. (938) It is there pointed out that on corn alone young pigs failed to make even fair gains, and that compared with this inefficient ration, 100 lbs. of tankage is worth more than 600 lbs. of corn. Well-grown pigs which were started on corn alone at an average weight of 150 lbs. stood this poor ration somewhat better, but even for feeding such older pigs, each 100 lbs. of tankage saved 505 lbs. of corn. These figures can not be taken as showing the actual money values of tankage, for several protein-rich supplements are usually available for swine feeding, and the actual feeding value of tankage will depend on the prices of the other supplements available.

Experiment station scientists have usually been able to secure tankage of high grade more readily than they could obtain a constant supply of skim milk or buttermilk. Hence they have quite commonly used tankage as a standard with which to compare other protein-rich supplements for swine. Accordingly, in this chapter the values of skim milk, wheat middlings, linseed meal, and several other supplements are compared directly with that of tankage. (958-61, 969, 973)

The best grades of tankage, which are often called "digester tankage," usually contain about 60 per ct. of crude protein and 6 to 10 per ct. of fat, thus furnishing nearly twice as much protein as linseed meal. High grade tankage produced by the large companies usually meets in composition the guarantees of the makers, and it is commonly in good mechanical condition, being dry and finely ground.

The lower grades of feeding tankage contain less crude protein, and usually carry more fat. Such products usually range in protein content from 40 to 50 per ct. Often such feeding tankage is produced at plants which render animals that have died from one cause or another. If care is taken at the plant to keep the finished tankage away from the incoming dead animals, which may be diseased, there should be no danger in feeding such tankage. Some of the smaller plants are not equipped with suitable drying and grinding apparatus and therefore the tankage they produce is suitable only for fertilizer. Little work has been done to determine the relative value of the various grades of tankage.[83] Commonly the protein content will furnish an approximate measure of the value per ton of various grades, tho some allowance should be made for the other ingredients. For example, a well-made tankage which contains only about 40 per ct. of crude protein and 12 per ct. fat will be worth slightly more than two-thirds as much as digester tankage containing 60 per ct. crude protein and only 6 per ct. fat, due to the higher fat content of the low-grade tankage. Such tankage also contains more bone than digester tankage, but digester tankage usually contains sufficient so that there

[83]Evvard, Iowa Rpt. 1918, pp. 19–20.

will be no deficiency of calcium or of phosphorus, when enough tankage is fed to balance the grains.

965. Important points in feeding tankage.—Tankage is so high in protein and hence so expensive a feed that every farmer who uses it should understand clearly the methods of feeding it most economically. Due to its richness in protein, only a relatively small proportion of high-grade tankage is needed to supplement corn or other grains. For pigs weighing 100 to 150 lbs. which are fed corn and tankage in dry lot, without pasture, 9 to 10 lbs. of tankage per 100 lbs. of feed is enough to balance the ration. Pigs over 150 lbs. need only 6 to 8 per ct. of tankage in their ration. To balance the ration of young pigs soon after weaning, it would be necessary to feed 14 to 15 per ct. of tankage with corn, but, as is pointed out later, much better results are usually secured with pigs when certain other supplements are fed in addition to tankage. (**966**) With barley, wheat, and rye less tankage is, of course, needed than with corn. Pigs on such protein-rich pasture as alfalfa, clover, cowpeas, or rape need only about half as much tankage as those in dry lot. For instance, pigs weighing 100 to 150 lbs., on good pasture, need only 5 lbs. of high grade tankage to every 95 lbs. corn.

It is pointed out elsewhere that pigs self-fed corn and tankage, free choice, in separate compartments of a self-feeder usually eat about the correct proportions of these feeds to make a well-balanced ration, no matter whether they are in dry lot or on pasture. Due to the convenience of this method of feeding and the saving of labor, it has become very popular thruout the corn belt. Tho good results are commonly secured when corn and tankage are thus self-fed, free choice, sometimes the pigs either over-eat on tankage, or else they fail to take enough to balance their ration properly. In such cases it may be necessary to discontinue free choice feeding and either self-feed them a mixture of ground corn and tankage in the proper proportions, or else self-feed the shelled corn and hand-feed the tankage.

When pigs are self-fed such combinations as barley and tankage or wheat and tankage, free choice, they frequently over-eat on tankage to such an extent as to increase the cost of the gains materially. Free choice feeding of such combinations is not, therefore, to be recommended generally. Since these grains should be ground or crushed for swine, probably the best plan, if self-feeding is to be practiced, is to mix the ground grain and tankage in the proper proportions to make a balanced ration and then self-feed the mixture. In determining how much tankage to use, the recommendations of the Morrison feeding standards may be safely followed. With tankage as the supplement, only the lower amounts of protein that are recommended in these standards need be supplied, as the proteins of tankage are efficient in balancing the proteins of the grains.

When pigs are hand-fed their rations, it makes no difference whether the tankage is mixed with the other feed in suitable proportions or

whether the proper amount to balance the ration is fed separately. There is no advantage in feeding the tankage in the form of a slop or in soaking it.

966. Tankage alone vs. tankage plus other supplements.—Tho tankage is one of the best protein-rich supplements for swine, recent experiments have shown in a striking manner that more efficient rations can be made than merely tankage and grain, especially for pigs not on pasture. Indeed, if young pigs under 50 lbs. in weight are kept on only corn and tankage continuously, without any green feed, not infrequently they will eventually fail to thrive, even if they are fed yellow corn, which is rich in the fat-soluble vitamine. (939)

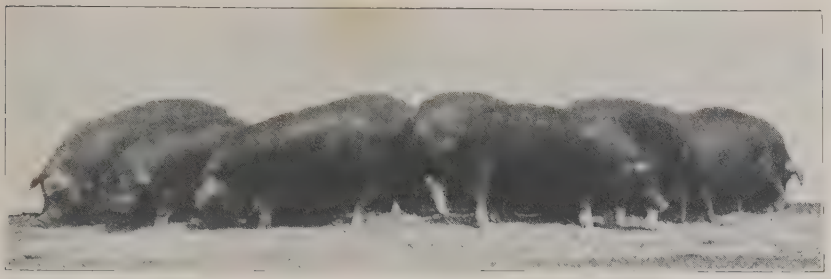
In trials at the Wisconsin Station by Morrison, Bohstedt, and Fargo a mixture of half linseed meal and half tankage has proven decidedly more economical than tankage alone for self-feeding, free choice, with corn to pigs on pasture. For dry lot feeding a mixture including some chopped alfalfa hay or alfalfa meal is advantageous, especially for young pigs. For example, very good results have been secured at the Wisconsin Station with a mixture of 2 parts tankage, 1 part linseed meal, and 1 part chopped alfalfa hay. (973) As is pointed out later, at the Iowa Station Evvard has found that pigs on pasture make slightly more rapid gains when self-fed a mixture of 40 to 50 parts of tankage and the balance of corn germ meal, along with corn, than when fed only tankage and corn. (980)

Careful investigations are just beginning to reveal the possibilities of making much more efficient rations for swine than have been known previously. Even our present knowledge shows, however, that the cost of pork production can often be reduced materially by using one of the combinations mentioned rather than feeding only grain and tankage, especially to young pigs not on pasture.

967. Blood meal.—Blood meal is used but relatively little for swine feeding, except sometimes for very young pigs, as tankage is usually a more economical source of protein. This animal by-product is low in both calcium and phosphorus, as it contains no bone. In a trial by Quick and Spencer at the Virginia Station[84] blood meal was worth $3 per 100 lbs. compared with skim milk at 25 cts. per 100 lbs. (271)

968. Fish meal.—Tho fish meal has for years been fed to stock in Europe, only recently has it been thus used in the United States. The composition of the better grades of fish meal is quite similar to that of digester tankage. Fish meal from various sources varies more or less in composition and quite probably in feeding value. Recent experiments have shown clearly that high-grade fish meal is even superior to tankage as a supplement to the grains in swine feeding. The following table summarizes the results of 11 trials in which fish meal has been compared with tankage as a supplement to corn for pigs in dry lot. The fish meal was in most cases the by-product of oil extraction from

[84]Va. Bul. 176.



TANKAGE ALONE IS NOT THE MOST EFFICIENT SUPPLEMENT

Especially for pigs not on pasture, tankage alone is less efficient as a supplement than tankage combined with certain other protein-rich feeds. These pigs, weighing 65 lbs. at the start, were fed yellow corn and tankage at the Wisconsin Station. They gained 1.04 lbs. a head daily.

EFFICIENT MIXTURE INCREASES GAINS OF PIGS

These pigs of the same age as those above, were fed a combination of tankage, linseed meal, and chopped alfalfa hay with yellow corn. They gained 1.36 lbs. a head daily and made cheaper gains than the first lot.

WHITE CORN AND TANKAGE WERE INEFFICIENT IN DRY LOT

These pigs were fed white corn and tankage in dry lot, without pasture, from a weight of 65 lbs. Due to the lack of the fat-soluble vitamine, they gained only 0.77 lb. a head daily. Compare them with the pigs of the same age fed yellow corn and tankage.

Middlings or Linseed Meal Are Satisfactory on Pasture

On good pasture, such as this, wheat middlings or linseed meal are satisfactory supplements to corn or other grains. On the other hand, they are inefficient when used as the only supplement for feeding young pigs in dry lot.

Fattening Old Sows on Excellent Pasture

For fattening old sows not as much protein is needed as for pigs, but it pays to balance the ration properly by feeding them a protein-rich supplement in addition to corn, even on good pasture.

menhaden herring caught off the Atlantic coast. A total of 145 pigs, averaging 77 lbs. in initial weight were fed for an average of 80 days in these trials.

*Fish meal vs. tankage as supplement to corn for pigs**

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain: Corn Lbs.	Feed for 100 lbs. gain: Fish meal or tankage Lbs.
Lot 1, Fish meal, 0.48 lb.	Corn, 5.7 lbs.....	1.58	370	33
Lot II, Tankage, 0.49 lb.	Corn, 5.6 lbs.....	1.42	403	37

*Hostetler, N. C. Station (Information to the authors); Morrison and Bohstedt, Wis. Station (Unpublished data); Robison (Ohio Bul. 349); Starkey, S. C. Station (Information to the authors); Vestal, Ind. Station (Information to the authors); Wilson and Kuhlman (S. D. Bul. 192); Ala. and Tenn. Stations (Data from U. S. D. A.).

In 10 out of the 11 trials fish meal produced larger and more economical gains than tankage. On the average the pigs fed fish meal gained 1.58 lbs. a head daily and required only 370 lbs. corn and 33 lbs. fish meal for 100 lbs. gain, while those fed tankage gained 1.42 lbs. and consumed 403 lbs. corn and 37 lbs. tankage for each 100 lbs. gain. In the majority of other trials in which fish meal has been compared with tankage in various rations, it has also proven superior,[85] but in a few instances tankage has been the more valuable.[86]

969. Wheat middlings, or shorts.—Standard wheat middlings, or shorts, are one of the most popular feeds for all classes of swine. Middlings are fairly high in protein and are rich in phosphorus, but are low in calcium. The proteins in middlings do not supplement the proteins of the grains very efficiently. Probably for this reason, pigs not on pasture, especially those which are young, do not make as good gains on only grain and middlings as when they are fed in addition a limited amount of some feed of animal origin, such as tankage or dairy by-products. If no animal feeds are available, then it is wise to include choice legume hay in the ration, as this will help overcome the deficiencies of the grain and middlings ration. As middlings contain only about 13 per ct. digestible crude protein, a much larger proportion is needed to balance the ration than with tankage or even linseed meal.

The following table summarizes the results of 6 trials in which standard middlings or shorts have been compared with tankage as the only supplement to corn for pigs not on pasture, which weighed 90 lbs. or over when placed on feed. In these trials 92 pigs, averaging 119 lbs. in weight were fed for 72 days on the average.

Standard middlings vs. tankage as a supplement to corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain: Corn Lbs.	Feed for 100 lbs. gain: Supplement Lbs.
Lot I,* Middlings, 2.64 lbs.	Corn, 3.35 lbs.....	1.33	266	201
Lot II,* Tankage, 0.66 lb.	Corn, 5.80 lbs.....	1.56	376	42

*Average of trials by Carmichael (Ohio Bul. 209); Erf and Wheeler (Kan. Bul. 192); Forbes (Ohio Bul. 213); Loeffel, Nebr. Station, (Information to the authors); Skinner and Cochel (Ind. Bul. 137); and Snyder (Nebr. Bul. 147).

[85]Ashbrook, U. S. D. A. Bul. 610; Loeffel, Nebr. Station, information to the authors; Weaver, Mo. Station, information to the authors.

[86]Evvard, Iowa Station, information to the authors; Thompson, Cal. Rpt. 1918–19.

These well-grown pigs fed middlings and corn made quite satisfactory gains. However, those fed tankage in place of middlings gained about one-fourth pound more a head daily and required considerably less total feed for 100 lbs. gain. In these trials each 100 lbs. of middlings replaced 55 lbs. corn plus 21 lbs. tankage, considering only the feed required for 100 lbs. gain, but not taking into account the fact that the pigs fed tankage were ready for market considerably sooner, due to their larger gains. From these figures one can readily estimate the actual value of middlings, thus fed, compared with corn and tankage at local prices. For example, with corn at 56 cts. a bushel and tankage at $60 a ton, middlings were worth less than $23.60 a ton. Middlings and grain alone will usually give much poorer results if fed to young pigs not on pasture than it did with these older animals.

Middlings give much better results when used as the only supplement for pigs on good pasture than in dry lot feeding. In 3 trials by Morrison, Bohstedt and Fargo at the Wisconsin Station[87] pigs self-fed middlings and corn, free choice, on alfalfa or oats, peas, and rape pasture gained 1.18 lbs. a head daily, in comparison with 1.30 lbs. for others self-fed tankage and corn. The pigs ate on the average only 0.30 lb. middlings per head daily, but this seemed to be enough to balance their ration quite well on the protein-rich pasture. In these trials middlings were actually worth twice as much per ton as corn.

Occasionally middlings are considerably lower in price per ton than corn. They may then be used as a substitute for corn, but as they are a less concentrated feed than corn, they are worth less per ton when thus used. In 2 trials by Morrison and Bohstedt at the Wisconsin Station[88] pigs self-fed standard middlings on rape pasture gained only 0.75 lb. a head daily and required 555 lbs. middlings for 100 lbs. gain. In comparison with these results pigs self-fed corn and tankage on rape pasture gained 1.28 lbs. and required only 382 lbs. corn and 30 lbs. tankage for 100 lbs. gain. Similarly, in a trial by Evvard at the Iowa Station[89] pigs self-fed middlings and tankage on rape pasture gained only 0.90 lb. a head daily, while others self-fed corn and tankage gained 1.34 lbs. Middlings fed as an entire substitute for corn are usually worth only 85 per ct. as much as corn per ton, or even less. Middlings alone make a very inefficient ration for young pigs not on pasture.

970. Adding middlings to corn and tankage.—Middlings have a considerably higher value when added to such a ration as grain and tankage or dairy by-products than when fed as the only supplement to grain for pigs in dry lot. This is shown clearly by the following table, which summarizes the results of 9 trials in each of which one lot of pigs has been fed only tankage, without pasture, while another lot was fed middlings in addition. These experiments included 283 pigs, averaging 140 lbs. in weight at the start and fed for an average of 60 days.

[87]Wis. Bul. 323, pp. 8–10; unpublished data.

[88]Unpublished data.

[89]Information to the authors.

*Adding standard middlings to corn and tankage**

Average ration		Daily gain	Feed for 100 lbs. gain		
		Lbs.	Corn Lbs.	Tankage Lbs.	Middlings Lbs.
Lot I, Tankage, 0.65 lb.	Corn, 6.4 lbs...	1.52	422	43	...
Lot II, Middlings, 1.94 lbs. Tankage, 0.49 lb.	Corn, 5.0 lbs...	1.67	293	30	120

*Av. of 5 trials by Waters, Kinzer, Wheeler, Wright, and King (Kan. Bul. 192); 3 by Weaver (Mo. Bul. 144); and 1 by Loeffel, Nebr. Station, (Information to the authors).

In each of these trials, except one, adding middlings to the ration of corn and tankage increased the gains. On the average the pigs fed middlings gained 1.67 lbs. a day, while the others fed only corn and tankage gained 1.52 lbs. In these trials 100 lbs. of middlings fully replaced 108 lbs. of corn and 11 lbs. of tankage. Thus, with these feeds at the prices stated previously, middlings were worth $28.20 a ton, or nearly 20 per ct. more than when fed in the relatively inefficient ration of middlings and corn.

In 6 trials[90] with young pigs averaging 67 lbs. in weight at the start, fed in dry lot, self-feeding wheat middlings in addition to corn and tankage did not make much improvement, and middlings were worth only about $21.40 a ton with corn at 56 ct. a bu. and tankage at $60 a ton. For such young pigs in dry lot, adding a little legume hay to the ration of corn and tankage seems to be much preferable to adding middlings. (**966**)

971. Flour wheat middlings; red dog flour.—*Flour wheat middlings* are preferred to standard middlings, or shorts, for young pigs, because they contain less fiber. Considering their higher content of both digestible crude protein and of total digestible nutrients, flour wheat middlings of a good grade are worth at least 13 per ct. more than standard middlings. Quite possibly for very young pigs there is even more difference in the feeding value. (**220**)

Red dog flour is fed commonly only to young pigs which need palatable, highly digestible feed, containing little fiber. The feeding value does not differ widely from that of the best grades of flour wheat middlings. (**219**)

972. Wheat bran; wheat mixed feed.—*Wheat bran* is too bulky to be fed in any large amount to fattening pigs, middlings being worth much more. Where clover or alfalfa hay, roots, or other cheap bulky feeds are not available, a limited amount of bran is excellent for brood sows, as it is bulky and also laxative. (**218**)

A good grade of *wheat mixed feed* (ship stuff) which contained all the middlings, was satisfactory when fed with an equal weight of corn meal to fattening pigs in a trial by Good of the Kentucky Station.[91] (**221**)

973. Linseed meal.—Linseed meal is quite widely used as a protein-rich feed for swine, especially in the northern states, and gives excellent

[90]Ferrin and Winchester, Kan. Cir. 78; Loeffel, Nebr. Station, information to the authors; Rice and Laible, Ill. Station, information to the authors; Robison, Ohio Bul. 356.

[91]Ky. Bul. 175.

results when fed under suitable conditions. Recent investigations have shown that the proteins of linseed meal are low in the same amino acids which are deficient in the cereal grains. (118) Also, linseed meal is lacking in lime, and hence fails to supplement the cereals in this regard.

For these reasons linseed meal and grain alone is a very unsatisfactory ration for young pigs which are not on pasture. On such a ration they will make poor gains, and often several will become stunted or suffer from paralysis or rickets. Even when a supply of calcium is added in the form of finely ground limestone, steamed bone meal, or ground rock phosphate, the results are not greatly improved. The primary deficiency in a ration of linseed meal and grain for young pigs seems to be the unbalanced nature of the protein, for if such feeds as tankage or dairy by-products, which furnish well-balanced animal proteins, are added to the ration, good results are secured.

For fattening well-grown pigs weighing 125 to 150 lbs. linseed meal and grain is a fair ration, probably due to the fact that such animals are storing protein in their bodies as lean meat much less rapidly than young pigs, and can therefore get along better on an unbalanced supply of food protein. Also, for young pigs on such protein-rich pasture as alfalfa, clover, rape, or oats-peas-and-rape, a combination of grain and linseed meal alone produces good gains, tho not as rapid or as economical as a combination of grain, linseed meal, and a little of some feed of animal origin, like tankage or dairy by-products.

These conclusions concerning linseed meal, which differ widely from statements generally made only a few years ago, are proven conclusively by the trials summarized in the following table. This gives first the results of 11 trials in which young pigs averaging 64 lbs. in weight at the start have been fed linseed meal and corn without pasture in comparison with others fed tankage and corn for about 100 days on the average. The next portion of the table gives the results of 10 other trials in which linseed meal and tankage have been compared as a supplement to corn for pigs averaging 135 lbs. when the experiments began. Last are given the results of 7 trials in which 73-lb. pigs were fed either linseed meal or tankage as a supplement to corn on alfalfa, rape, or oats-peas-and-rape pasture. The trials with young pigs averaged over 100 days in length, while the older pigs were fed 71 days on the average.

The young pigs fed linseed meal and corn in dry lot without pasture gained only 1.02 lbs. a day on the average, while those on tankage gained 1.31 lbs. In several of the trials some of the pigs on linseed meal became unthrifty and a few became paralyzed. Had the pigs been started on this ration still earlier the results would have been still poorer. Either limestone or rock phosphate was added to the ration in 3 of the tests, but this did not help greatly.

By computation it will be found that for these young pigs not on pasture it took 185 lbs. linseed meal and 115 lbs. corn to replace each

100 lbs. of tankage. Even without considering the injurious effect of this ration on some of the pigs, linseed meal was worth no more per ton than corn in these trials.

Compared with these poor results, linseed meal and corn produced nearly as good gains as tankage and corn when fed to well-grown pigs or to pigs on first-class pasture. Fed under such conditions, 100 lbs. of linseed meal was worth approximately as much as 57 lbs. of tankage plus 25 lbs. of corn. From this, one can readily determine the value of linseed meal with feeds at local prices. For instance, with corn at 56 cents a bushel and tankage at $60 a ton, linseed meal thus fed would be worth about $39 a ton. On poor pasture, such as blue grass in midsummer, linseed meal does not give such good results as the only supplement to grain.[92]

Linseed meal vs. tankage as supplement to corn for pigs

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Feed for 100 lbs. gain Supplement Lbs.
*Young pigs in dry lot**				
I. Linseed meal, 0.61 lb.	Corn, 4.0 lbs.....	1.02	398	61
II. Tankage, 0.43 lb.	Corn, 4.7 lbs.....	1.31	360	33
Well-grown pigs in dry lot†				
I. Linseed meal, 0.69 lb.	Corn, 5.3 lbs.....	1.46	374	46
II. Tankage, 0.38 lb.	Corn, 5.8 lbs.....	1.50	399	25
Young pigs on good pasture‡				
I. Linseed meal, 0.48 lb.	Corn, 4.7 lbs.....	1.34	359	35
II. Tankage, 0.30 lb.	Corn, 5.0 lbs.....	1.42	354	21

*Average of 7 trials by Robison (Ohio Bul. 349 and information to the authors); 2 by McCampbell, Ferrin, and Winchester (Kan. Cir. 78); and 2 by Morrison and Bohstedt, Wis. Station (Unpublished data).
†Average of 4 trials by Skinner and Cochel (Ind. Buls. 126 and 137); 2 by Forbes (Ohio Bul. 213); 2 by Snyder (Nebr. Bul. 147); 1 by Hays (Del. Bul. 124); and 1 by Robison (Ohio Bul. 316).
‡Average of 3 trials by Morrison, Bohstedt, and Fargo (Wis. Bul. 323 and unpublished data); 2 by Grimes (Penn. Bul. 168); and 2 by Robison (Ohio Bul. 349).

The highest value can not usually be secured from linseed meal when it is used as the only supplement to the grains, even for well-grown pigs or those on pasture. However, when linseed meal is combined with a small amount of tankage or dairy by-products, excellent results are secured. In fact, in each of 3 trials by Morrison, Bohstedt and Fargo at the Wisconsin Station[93] pigs self-fed, free choice, shelled corn and a mixture of half tankage and half linseed meal on good pasture have made more rapid gains than others fed tankage as the supplement. Thus fed, linseed meal has been worth as much as tankage, pound for pound, showing the saving possible thru efficient combinations of feeds. For pigs fed corn in dry lots, a mixture of 1 part linseed meal, 1 part chopped alfalfa hay, and 2 parts tankage has been superior to tankage or to a mixture of only tankage and linseed meal. This is apparently due to the legume hay furnishing some nutritive factor partially deficient in the ration of corn, linseed meal, and tankage.

Where no animal feeds, like tankage or dairy by-products, are available to feed with linseed meal and grain, better results will usually be

[92]Evvard, Iowa Station, information to the authors.

[93]Wis. Bul. 323, pp. 8–9; unpublished data.

secured if legume hay is added to the ration of grain and linseed meal, even if the grain is yellow corn. (**939**) For example, in 4 trials[94] pigs which ate 0.3 lb. of alfalfa hay a head daily in addition to corn and linseed meal gained 0.34 lb. more a head daily than those fed no alfalfa hay. In these trials each 100 lbs. of hay actually saved on the average 65 lbs. of linseed meal and 467 lbs. corn, compared with the results on the inefficient ration of only linseed meal and corn.

When pigs not on pasture are self-fed linseed meal and grain, free choice, they often will not eat enough linseed meal to supply a sufficiency of protein. In such cases the linseed meal had best be mixed with ground grain. Even then the gains will not be as rapid as on a more efficient ration. (**966**) It is often beneficial, especially with brood sows, to add a small amount of linseed meal to the ration, because of its beneficial laxative effect.

974. Cottonseed meal.—As now prepared, cottonseed meal is poisonous to swine. All the various proposed ways for safely feeding this meal have failed under careful and continued tests. Pigs thrive at first on the meal, but often in from 4 to 6 weeks some die—not all, as a rule—but so many that all possible profits from the use of this feed are lost. Some few feeders continue to use the meal, experience enabling them to avoid most of the losses. If cottonseed meal is not fed continuously for over 40 days or does not form over one-sixth to one-seventh of the ration (which is all that is needed to balance it), and if the pigs are freely supplied with green forage or grazed on pasture, the risk from this feed is lessened. Burns concludes from trials at the Texas Station[95] that it is not advisable to feed more than 0.5 lb. of cottonseed meal daily per 100 lbs. live weight to any class of hogs for a very long period, and if the meal is to be fed for quite a long time, then it is best not to feed over 0.35 lb. daily per 100 lbs. live weight.

It is considered safe to have pigs follow steers which are being fed cottonseed meal, for the meal does not seem to be poisonous after passing thru the cattle. Care should always be taken that the steers do not throw so much meal out of the feed boxes that the pigs may be poisoned by eating such waste meal. (**249**)

975. Field peas.—Field peas are not commonly used for swine feeding, as they are usually expensive compared with other available feeds. (**261**) As is pointed out later, in certain districts of the West pigs are often fattened by turning them into fields of mature field peas and allowing them to hog down the crop. When field peas are low enough in price to be an economical feed for swine, they may be used as a supplement to corn or other grains. In 2 trials at the Idaho Station[96] Hickman found a mixture of 1 part field peas and 3 parts barley, plus 5 per ct. of tankage,

[94]Average of 2 trials by Morrison and Bohstedt (unpublished data), and 1 each by Gramlich, Nebr. Bul. 175, and by Robison, Ohio Bul. 349.

[95]Am. Soc. Anim. Production, Proceedings 1915–16, pp. 15–20.

[96]Idaho. Bul. 122, p. 27.

the best of several combinations tested. In these trials and also in an experiment by Hislop at the Washington Station[97] it was found desirable to add a small amount of a feed of animal origin, like tankage or skim milk, to a ration of grain and peas, for pigs not on pasture. Sometimes pigs fed peas alone in dry lot do not thrive, but in other instances they make quite good gains. Such a ration is, however, usually uneconomical and much better results are secured when the peas are fed with grain, the peas forming only half the ration or less.

976. Cull beans.—Cull table beans are satisfactory for swine when thoroly cooked and fed with carbonaceous feeds. At the Michigan Station[98] in 3 trials Shaw and Anderson found that pigs fed equal parts of cooked cull beans and corn meal made average gains of 1.5 lbs. per head daily, requiring 406 lbs. of feed for 100 lbs. of gain. Pigs fed beans alone gained only 1.1 lbs. and required 421 lbs. of beans for 100 lbs. gain. Salt should always be added to the water in which the beans are cooked. When beans are fed alone or in excess they produce a soft pork lacking in quality. (**263**)

977. Soybeans; soybean oil meal.—Not only do soybeans contain nearly as much crude protein as linseed meal but the protein is well-balanced in composition so that it supplements the proteins of the cereal grains quite efficiently. Doubtless because of this, trials have shown soybeans to have a higher value than most protein-rich feeds of plant origin. Soybeans are, however, low in calcium. Also, their high fat content sometimes makes them rather unpalatable to swine receiving them continuously. The following table summarizes the results of 12 trials with a total of 151 pigs in which ground soybeans were compared with tankage as the only supplement to corn for dry lot feeding. In these trials pigs averaging 117 lbs. in weight were hand-fed for an average of 70 days:

Soybeans vs. tankage as a supplement to corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Supplement Lbs.
Lot I,* Soybeans, 1.00 lb.	Corn, 4.8 lbs.....	1.43	336	71
Lot II,* Tankage, 0.73 lb.	Corn, 5.4 lbs.....	1.58	340	46

*Average of 3 trials by Carmichael (Ohio Bul. 209); 3 by Good (Ky. Bul. 175 and Cir. 20); 2 by Robison (Ohio Buls. 316, 349); 2 by Skinner and Cochel (Ind. Buls. 108, 137); and 1 each by Erf (Kan. Bul. 192) and Forbes (Ohio Bul. 213).

On the average the pigs fed soybeans and corn made nearly as large gains as those fed tankage and corn, and required only 336 lbs. corn and 71 lbs. soybeans for 100 lbs. gain. In these trials 100 lbs. ground soybeans replaced 65 lbs. tankage plus 5 lbs. corn, not considering the fact that the gains were a trifle less rapid on the soybeans. With tankage at $60 a ton and corn at 56 cts. a bushel, this would give soybeans a value of about $40 a ton. A similar high value for soybeans in comparison with tankage was secured in 2 trials by Robison[99] when they were fed as the supplement to corn on pasture.

[97]Wash. Bul. 153, p. 8. [98]Mich. Bul. 243. [99]Ohio Bul. 349.

Where pigs have been self-fed soybeans and corn, free choice, the results have not been nearly as favorable. In 5 trials,[100] pigs averaging 98 lbs. in weight gained only 1.15 lbs. a head daily when self-fed soybeans and corn, while on tankage and corn the average daily gain was 1.69 lbs. and the pigs required 17 per ct. less feed for 100 lbs. gain. These poor results were caused in part at least, by the pigs failing to eat enough of the fatty soybeans to balance their ration.

When soybeans are used as the only supplement to grain for pigs not on good pasture, a mineral supplement should be added to supply calcium. (**916**) Sometimes pigs fed soybeans and grain alone in dry lot become unthrifty and may even suffer from paralysis.[101] In such cases choice legume hay should be included in the ration, as this will usually prevent the trouble. Soybeans are quite commonly ground for swine, but this is probably unnecessary, unless such preparation is required to get them to eat enough soybeans to balance their ration. (**256**)

Soybean oil meal, from which most of the fat has been extracted, contains 40 to 50 per ct. crude protein, and is much more palatable to swine than soybeans. (**257**) Therefore, it is one of the very best protein-rich concentrates of plant origin for pork production. Soybean oil meal has been compared directly with tankage as the supplement to corn for pigs in dry lot in 6 trials summarized in the following table. In these trials 90-lb. pigs were self-fed either soybean oil meal and corn or tankage and corn or else were hand-fed the same feeds for periods averaging 71 days:

Soybean oil meal vs. tankage as a supplement to corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Supplement Lbs.
*Lot I,** Soybean oil meal, 0.58 lb.	Corn, 5.2 lbs.....	1.55	342	36
*Lot II,** Tankage, 0.48 lb.	Corn, 5.7 lbs.....	1.62	350	30

*Average of 5 trials by Robison (Ohio Bul. 349) and 1 by Vestal, Indiana Station (Information to the authors).

No matter whether the pigs were self-fed, free choice, or hand-fed, the gains were nearly as rapid on soybean oil meal as on tankage. In these trials 100 lbs. soybean oil meal replaced on the average 83 lbs. tankage and 22 lbs. corn. With tankage at $60 a ton and corn at 56 cts. a bushel, this would give it a value of over $50 a ton. In one trial by Robison, in which soybean oil meal unusually high in fat was used, poor results were secured, similar to those sometimes occurring with soybeans. In feeding soybean oil meal it should be borne in mind that it is low in calcium. (**916**)

978. Cowpeas.—In the South cowpeas are of great importance in economical pork production. (**262**) Most commonly pigs are turned into

[100]Average of 2 trials by Vestal, Ind. Station, information to the authors; and 1 each by Griswold, Miss. Station, information to the authors; Morrison and Bohstedt, unpublished data; and Robison, Ohio Bul. 349.

[101]Robison, Ohio Bul. 349.

a field of cowpeas and corn after the corn ears and perhaps some of the cowpeas have been picked. Sometimes, however, the cowpea seed is used as a supplement to corn or other carbonaceous feeds. Trials at the Alabama Station[102] show that a mixture of cowpeas and corn produces more economical gains than corn alone or cowpeas alone, just as we would expect from the chemical composition of these feeds. In these trials pigs fed half cowpeas and half corn required only 414 lbs. feed on the average for 100 lbs. gain, while those fed corn alone needed 68 lbs. more.

979. Peanuts; peanut meal and peanut feed.—Peanuts are of great importance in the South for swine feeding. Commonly the pigs are turned into the fields to do their own harvesting, as is pointed out later. If pigs are fattened on peanuts alone, soft pork is produced, but this may be largely overcome by finishing them on suitable feeds after they are taken from the peanut pasture. (**1005**)

Peanut meal, or *peanut oil meal,* the by-product resulting from the production of peanut oil from hulled peanuts, is one of the most valuable protein-rich feeds of plant origin. (**258**) Not only does such meal contain over 40 per ct. crude protein, but also the protein is of such character that it is an efficient supplement to the cereal grains. Futhermore, there is no trouble from soft pork, if peanut meal relatively low in fat content is fed and only enough is used to balance the ration; for example, one part of peanut meal to 5 or 6 parts of corn or grain sorghum.

In 4 trials at the Arkansas, Iowa, Ohio, and Texas Stations[103] pigs fed peanut meal and corn gained as much as others fed tankage and corn. They required 343 lbs. corn and 68 lbs. peanut meal for 100 lbs. gain, while the pigs fed tankage required 391 lbs. corn and 35 lbs. tankage. Good results were secured in dry lot feeding as well as with pigs on pasture, and in self-feeding, free choice, and in hand-feeding alike. In these trials 100 lbs. peanut meal was equal in feeding value to 71 lbs. grain plus 52 lbs. tankage.

The value of *peanut feed,* from unhulled peanuts or partially hulled nuts from which most of the oil has been expressed, will depend chiefly on the amount of crude protein it contains in comparison with meal from hulled nuts. In trials by Burk at the Texas Station[104] when pigs were fed a ration consisting of 29 per ct. peanut feed from unhulled nuts (ground whole pressed peanuts) and 71 per ct. milo chops, soft pork was produced. Had the peanut feed formed a smaller part of the ration, the pork would probably have been satisfactory. In 3 trials at the Kansas, Mississippi, and Texas Stations[105] in which peanut feed has been com-

[102]Duggar, Ala. Bul. 82; Gray, Duggar, and Ridgeway, Ala. Bul. 147.

[103]Dvorachek and Sandhouse, Ark. Cir. 45; Evvard, Iowa Station, information to the authors; Robison, Ohio Bul. 349; Burk, Tex. Bul. 201.

[104]Tex. Buls. 201, 228.

[105]McCampbell, Kan. Cir. 78; Griswold, Miss. Station, information to the authors; Burk, Tex. Bul. 201.

pared with tankage as a supplement to corn or milk, 100 lbs. of peanut feed has been worth as much as 46 lbs. grain plus 37 lbs. tankage. As will be noted, this is much lower than the value of peanut meal from hulled nuts, given in the preceding paragraph.

980. Gluten feed; corn germ meal.—But little *corn gluten feed* is fed to swine, for it is much more valuable for cattle than for hogs. (**210**) Not only is it a rather bulky feed, but also the protein it supplies is not well suited to balance the proteins of the cereal grains. (**937-8**) Furthermore, it is not very palatable to swine. In trials by Evvard at the Iowa Station[106] adding gluten feed to a ration of corn and tankage, for pigs either in dry lot or on pasture, did not prove economical with feeds at usual prices. Similar results were secured by Loeffel at the Nebraska Station[107] when gluten feed was added to a ration of corn, tankage, and alfalfa hay, fed to fattening pigs in dry lot. Also in a trial by Ashby at the Minnesota Station,[108] it was not profitable to add gluten feed to a ration of corn feed meal, shorts, and tankage. Fed as the only supplement to corn, gluten feed has not given good results either in dry lot feeding or with pigs on pasture.[109]

Corn germ meal (also called *corn oil cake meal* or *germ oil meal*), is the by-product left after most of the corn oil is pressed from corn germs. (**212**) It contains only about one-third as much crude protein as tankage. Several trials[110] to study the value of corn germ meal have been carried on by Evvard at the Iowa Station, Robison at the Ohio Station, and Skinner and Starr at the Indiana Station. These trials show that this feed should be fed as a partial substitute for tankage or dairy by-products, for it gives good results when thus used. On the other hand, poor returns are usually secured when it is fed as the only supplement to corn for pigs in dry lot. When fed with grain as the only supplement to pigs on good pasture the gains are quite satisfactory, but corn germ meal, thus fed, has been worth little or no more than corn, ton for ton. During the World War when corn germ meal was sometimes lower in price per ton than corn, it was occasionally used as a substitute for that grain in swine feeding, but, thus used, it has not been equal to corn in feeding value. Skinner and Starr found corn germ meal resulting from hominy manufacture better than that secured as a by-product from starch plants. When fed in too large amounts, corn germ meal may cause scours, and it is often unpalatable to pigs.

Evvard has found that when pigs on pasture are self-fed, free choice, corn and also a mixture of corn germ meal and tankage, the gains are somewhat more rapid than if tankage is used as the only supplement to

[106]Iowa Rpts. 1917–18, pp. 21–22; 1919–20, p. 24.

[107]Information to the authors.

[108]Minn. Rpt. 26, pp. 49–50.

[109]Evvard, Iowa Station, information to the authors; Hays, Del. Bul. 124.

[110]Iowa Station, information to the authors; Ohio Bul. 349; Ohio Mo. Bul. 57; Ind. Bul. 219.

corn. For example, in one trial pigs self-fed corn and tankage, free choice, on timothy and bluegrass pasture gained 1.13 lbs. a head daily and consumed 357 lbs. corn and 42 lbs. tankage for 100 lbs. gain. Another lot fed a mixture of 3 parts corn germ meal and 1 part tankage instead of tankage gained 1.22 lbs. a head daily and required only 309 lbs. corn plus 19 lbs. tankage and 58 lbs. corn germ meal for 100 lbs. gain. In this trial 100 lbs. of corn germ meal saved 40 lbs. of tankage and 83 lbs. of corn. With corn at 56 cents a bushel and tankage at $60 a ton, this gave corn germ meal a value of $40.60 a ton. However, in 3 other trials by Evvard corn germ meal has had a lower value when added to corn and tankage for pigs on good rape pasture. On the average, in these trials the pigs fed corn with tankage as the only supplement gained 1.42 lbs. a head daily and required 350 lbs. corn and 28 lbs. tankage for 100 lbs. gain. Those fed corn germ meal in addition gained 1.44 lbs. and required 329 lbs. corn plus 19 lbs. tankage and 29 lbs. corn germ meal for 100 lbs. gain. In these trials 100 lbs. corn germ meal saved 72 lbs. corn and 31 lbs. tankage, making corn germ meal worth $33.00 a ton, with corn and tankage at the previous prices.

In 5 trials[111] in which corn germ meal has been added to a ration of corn and tankage for pigs in dry lot, the results differ widely. On the average, the gain has not been increased over that made by pigs fed only corn and tankage. In these trials 100 lbs. of corn germ meal saved 52 lbs. corn and 44 lbs. tankage. Evvard prefers a mixture of half or less of corn germ meal and the balance of tankage to a mixture containing a larger proportion of corn germ meal.

981. Miscellaneous protein-rich feeds.—*Velvet beans* have not proved to be a satisfactory feed for pigs, when the beans have formed any considerable part of the ration.[112] This has been the case no matter whether the beans have been fed shelled, ground, or in the pod, or whether velvet bean feed has been used. This may be explained by the fact that the proteins of the velvet bean are not well digested when the beans are fed uncooked.[113] Also, it is possible that the beans contain a substance which is somewhat poisonous to swine when fed in large amounts. When only 20 per ct. of the ration consisted of velvet bean feed, with the rest made up of corn, peanut meal, and alfalfa meal, Lindsey secured satisfactory gains on pigs in a test at the Massachusetts Station.[114] Good gains were also secured in a trial by the United States Department of Agriculture when pigs were fed soaked velvet bean meal with corn and fish meal;[115] (264)

[111]Evvard, Live Stock Health Jour. Nov. 1, 1920; Robison, Ohio Mo. Bul. 57; Skinner and Starr, Ind. Bul. 219.

[112]Dvorachek, Ark. Cir. 45; Good and Mann, Ky. Cir. 20; Griswold, Miss. Station, information to the authors; Scott, Fla. Bul. 141; Templeton, Ala. Bul. 213.

[113]Finks and Johns, Am. Jour. Physiol., 57, 1921, p. 61; Jones, Finks, and Waterman, Jour. Biol. Chem., 52, 1922, p. 209.

[114]Mass. Bul. 197.

[115]U. S. D. A. Rpt. Bur. Anim. Indus. 1918–19.

Cocoanut meal, when not rancid, may be used in place of such feeds as wheat middlings or linseed meal for swine feeding, but, like these feeds, it does not give good results if fed as the only supplement to young pigs not on pasture.[116] In trials by Thompson and Voorheis at the California Station,[117] cocoanut meal has been worth about as much as barley per ton for fattening hogs, when one part of cocoanut meal was fed with 3 or 4 parts of barley. In one test by Fjeldsted and Potter at the Oregon Station[118] cocoanut meal gave good results when fed with barley, but in 2 other trials it was unpalatable to the pigs. In a trial by Hays at the Delaware Station[119] cocoanut meal and corn produced as rapid gains on 150-lb. pigs in dry lot as did tankage and corn. (**260**)

Buckwheat middlings gave poor results when fed as the only supplement to corn for young pigs not on pasture, in trials by Robison at the Ohio Station,[120] thus resembling wheat middlings and linseed meal. (**969, 973**) Doubtless good results would be secured if dairy by-products, tankage, or legume hay were added to such a ration. (**244**)

Dried distillers' grains are not usually fed to swine. They are not relished by pigs when fed as the only concentrate allowance, and, moreover, are too bulky a feed to be supplied in large amounts to fattening pigs. However, in a trial by Good and Smith at the Kentucky Station[121] pigs fed 3.3 lbs. ground corn and 0.66 lb. dried distillers' grains per head daily in dry lot gained 0.88 lb. and required 444 lbs. concentrates for 100 lbs. gain. Others fed corn and 0.51 lb. dried distillers' grains on good pasture gained 1.03 lbs. a head daily and consumed only 300 lbs. concentrates for 100 lbs. gain. (**283**)

Distillery slop may be fed to pigs with good results when such concentrates as grain are supplied in addition, for the slop is too watery to be fed alone.

Sunflower seed proved satisfactory when equal parts of the seed and corn were fed to 100-lb. pigs in a trial by Weaver at the Missouri Station.[122] This ration compared favorably with a ration of corn and tankage. Sunflower seed alone produced poor gains. It has been pointed out before that sunflowers are not generally a profitable grain crop in the United States. (**259**)

III. Forage Crops, Pasture, and Other Succulent Feeds; Hay

982. Importance of forage crops and pasture.—Pastures are so important in pork production that they often make all the difference between profit and loss. Few facts in swine feeding have been so clearly proven, both by scientific experiments and in the common experience of successful farmers, as the high value of pasture or forage crops for all classes of swine.

[116]Robison, Ohio Bul. 349.
[117]Cal. Bul. 335.
[118]Ore. Bul. 165.
[119]Del. Bul. 124.
[120]Ohio Bul. 349.
[121]Ky. Bul. 190
[122]Mo. Bul. 189, pp. 22–3.

Pasture is valuable for all swine, but it is especially important for young pigs. This is because good pasture crops are rich in the body-building materials needed in liberal amounts by young growing animals. Such crops are rich in protein and, moreover, the protein is of the right kind or quality to supplement effectively the proteins of the common farm grains, which are not well-balanced in composition. Pasture crops are also rich in mineral matter, particularly lime and phosphorus, which are needed in large amounts by young animals. Last, but not least important, green pasture crops are rich in all the vitamines, which scientists have recently found to be necessary for the growth and health of animals.

Due to the fact that good pastures furnish a large amount of feed of such excellent character, far greater gains are made on a given amount of grain or other concentrates when fed to pigs on pasture than to those not provided with pasture. Moreover, only about half as much expensive protein-rich supplements, such as skim milk, tankage, linseed meal, or wheat middlings are needed by pigs on pasture. Therefore, they make much cheaper gains than those less fortunate ones which have none.

Pigs on pasture not only make cheaper gains, but the green, succulent feed and the exercise they get aid greatly in keeping them thrifty and in good condition. Merely from a sanitary standpoint, it is highly important that swine, and especially pigs, be out on uncontaminated pasture all thru the growing season. Nothing is more important than this in preventing serious trouble from worms and filth-borne diseases. (1039)

Another important advantage of having swine on pasture is the fact that then the manure is evenly distributed over the field and none is wasted, as is the case when pigs are fed in dry lot.

Because of the many virtues and economies of pasture for swine, every one who expects a profit from pork production should provide an abundance of good forage for all his hogs from early spring to late fall. There should be pasture for the brood sows and their litters in the spring; pasture for the growing, fattening pigs from weaning time until market or until frost kills the crop; pasture for the brood sows and boar in summer; and good pasture for any fall litters.

The choice of forage or pasture crops for any particular section will depend primarily on the soil and climatic conditions. The following paragraphs, which discuss the merits of many forage crops, show that alfalfa, the clovers, rape, soybeans, cowpeas, blue grass, rye, and several other crops all have decided merits and provide valuable swine pastures in various sections of the country or for certain seasons of the year. In general, those pasture crops are best in a given section which give high yields of palatable, nutritious forage over a long season, at a low cost for growing the crop. The forage should be rich in protein and also in mineral matter, especially in calcium and phosphorus. It should also endure grazing well, and not merely furnish pasturage for but a few weeks of the season. As will be noted in the following pages, over much

of the country most of these essentials are possessed by alfalfa, the clovers, and rape, or mixtures such as oats-peas-and-rape.

The high value of pasture crops in pork production is clearly shown in the following table. This summarizes first the results of 11 comparisons in each of which one lot of pigs averaging 52 lbs. in weight has been fed a well-balanced ration of corn and tankage in dry lot, while another lot has been full-fed corn and tankage on alfalfa or clover pasture. The latter part of the table gives the results of 12 similar comparisons in which 56-lb. pigs have been fed corn and tankage on rape pasture in comparison with others in dry lot. In some of the trials the pigs were self-fed and in others hand-fed all they would eat, both in dry lot and on pasture. In several of the early trials of this nature, the pigs on pasture were fed just as large a proportion of tankage or other supplement as those in dry lots. The results of such trials are not included in these averages, for one of the advantages of pasture crops is that pigs on good pasture need only about half as much protein-rich supplement to balance their ration as those fed in dry lots.

Value of pasture for growing, fattening pigs

Average ration	Length of trials Days	Daily gain Lbs.	Concentrates per 100 lbs. gain	
			Corn Lbs.	Tankage Lbs.
*Alfalfa or clover vs. no pasture**				
Lot I, pigs on pasture				
Corn, 4.9 lbs				
Tankage, 0.31 lb. Pasture	113	1.31	370	24
Lot II, no pasture				
Corn, 4.6 lbs				
Tankage, 0.44 lb	133	1.13	410	40
Rape vs. no pasture†*				
Lot I, pigs on rape				
Corn, 4.8 lbs.				
Tankage, 0.29 lb. Pasture	112	1.35	360	21
Lot II, no pasture				
Corn, 4.1 lbs				
Tankage, 0.42 lb	121	1.04	399	41

*Average of 8 trials by Morrison and Bohstedt, Wis. Station (Unpublished data); and 3 by Robison (Ohio Bul. 343).

†Average of 5 trials by Morrison and Bohstedt, Wis. Station (Unpublished data); 4 by Robison (Ohio Buls. 343 and 349); 2 by Grimes (Penn. Bul. 168); and 1 by Evvard (Iowa Bul. 136).

The first portion of the table shows that the pigs fed corn and tankage on alfalfa or clover pasture gained 1.31 lbs. and required only 370 lbs. corn and 24 lbs. tankage for 100 lbs. gain. Compared with these excellent results, those fed the well-balanced ration of corn and tankage in dry lot gained only 1.13 lbs. and required about 11 per ct. more corn and 67 per ct. more tankage for each 100 lbs. gain. In these trials 19 pigs on the average were carried on the legume pasture from a weight of 52 lbs. to the end of the pasture season. An acre of alfalfa or clover pasture saved 1,149 lbs. corn plus 468 lbs. tankage, compared with dry lot feeding, on the average. In addition, considerable hay was cut from the pasture lots during the season in nearly all of the trials. This amounted

to 2,326 lbs. per acre in 8 trials in which the weights of hay were reported. With corn at 56 cts. a bushel and tankage at $60 a ton, the saving of feed per acre of pasture was $25.53. Crediting the hay removed at $7.50 a ton, a fair price for standing alfalfa or clover, makes the total value of an acre of pasture about $34.25. In this computation no credit is given for the more rapid gains of the pigs on pasture, which would often enable one to sell them early in the fall, before prices slumped. Also no credit is included for the fertility added to the soil thru the growth of the legume and the manure produced from the corn and tankage fed, practically all of which is saved when pigs are fed on pasture.

The last part of the table shows a similar saving when rape pasture was compared with dry lot feeding. On the average the pigs on rape required 39 lbs. less corn and 20 lbs. less tankage for each 100 lbs. gain than those fed in dry lot. An acre of rape saved 1,607 lbs. corn and 799 lbs. tankage, compared with dry lot feeding. Furthermore, at the end of the trials the pigs on pasture weighed over 200 lbs. on the average, and were ready for market, while those which had no pasture weighed only 183 lbs. Had all the pigs been carried to the same market weights, as was done in the Wisconsin trials, there would have been even a greater difference in the amounts of feed required for 100 lbs. gain by the pigs on pasture and those in dry lot.

983. Methods of feeding pigs on pasture.—After providing plenty of good pasture for all his swine, the next question which arises in the mind of a farmer is whether he shall full-feed grain or other concentrates to pigs on pasture, or whether it will be more profitable to limit the amount of concentrates. This matter is fully discussed in the previous chapter, where it is pointed out that the answer will depend primarily on the relative price of grain and pasture and on whether or not it is the desire to finish the pigs for an early fall market. In all cases it is usually necessary to feed pigs on pasture at least 2 lbs. of concentrates daily per 100 lbs. live weight, to keep them growing thriftily. (**924**) Many young pigs are stunted because their owners fail to appreciate the structure of their digestive tracts and expect them to live on pasture alone, or on pasture with too scanty a supply of grain.

Self-feeding growing and fattening pigs on pasture is an economical and labor saving method of pork production, where they are to be finished for an early market. The merits of self-feeding versus hand-feeding are discussed in the preceding chapter. (**925-7**)

Pigs on pasture should be provided with shade, and an abundant supply of fresh water. Automatic waterers will be found to be convenient and labor saving devices which give excellent satisfaction when properly adjusted. Salt should also be supplied at all times. Pigs which are fed well-balanced rations on pasture are much less apt to root than dissatisfied pigs fed inefficient rations, such as corn alone. It is often not necessary to ring spring pigs which are to be sold in the fall at the

close of the pasture season, for they are less apt to root than are hogs. However, the pasture lots must be watched closely, and if the pigs start rooting badly, it will be necessary to ring them at once, especially if they are on a permanent pasture, such as alfalfa or blue grass. Even if fed good rations, pigs are apt to begin rooting after hard summer or fall rains, to get the angle worms which then come close to the surface of the ground. This is not surprising, for in a state of nature, the hog gained his living largely by rooting. On annual crops, such as rape, it is not usually necessary to ring pigs if they are fed well-balanced rations.

984. Feeding a supplement with corn on pasture.—All forage crops, at the immature stages when commonly used for pasture, are much richer in protein than the same crops when nearly mature. (**81, 310**) It will be noted in Appendix Table III that the common forage crops used for swine all have as narrow a nutritive ratio as wheat middlings, and in many cases the forage plants are even richer than middlings in protein at the stages of growth when pastured. This is true with alfalfa, red clover, rape, oats, rye, and even blue grass.

Due to the richness of the common pasture crops in protein and also because of their other virtues, young pigs fed only corn on good forage will usually make fair gains. Especially when pigs are full fed on corn they will not, however, eat enough of the bulky green forage to balance their ration entirely. Hence they will make much more rapid gains if some protein-rich concentrate is added to balance the ration. This is shown clearly in the following table, which summarizes the results of 7 trials in each of which one lot of spring pigs, averaging 49 lbs. in weight, was fed only corn on rape pasture, while another lot was fed corn plus a small amount of tankage:

Adding a supplement to corn and good pasture

Average ration	Length of trial Days	Daily gain Lbs.	Concentrates for 100 lbs. gain Corn Lbs.	Tankage Lbs.
Lot I,* Corn, 3.7 lbs. Rape	142	0.88	427	..
Lot II,* Corn, 4.3 lbs. Tankage, 0.24 lb. Rape	120	1.25	344	20

*Average of 5 trials by Robison (Ohio Buls. 343 and 349); and 2 by Evvard (Am. Soc. Anim. Prod., Proceedings, 1913, and information to the authors).

The pigs fed 0.24 lb. of tankage a head daily in addition to corn on rape pasture were more thrifty, ate more feed, and made much more rapid and economical gains. In these trials each 100 lbs. of tankage saved 415 lbs. of corn.

It should be pointed out that in these trials only enough tankage was fed to balance corn on good pasture. This requires only about half as much as when the pigs are fed corn in dry lot. Several investigators and many farmers have disregarded this fundamental fact that pasture crops save expensive protein-rich feeds, and have fed as much tankage or other protein-rich supplement to pigs on pasture as would have been

ALFALFA IS UNEXCELLED AS A PASTURE CROP FOR SWINE

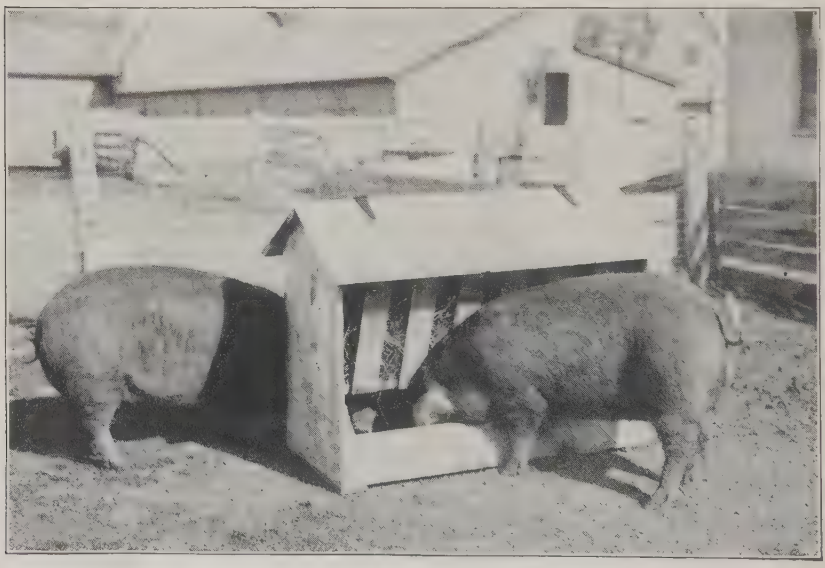
Where it thrives, alfalfa provides pasturage over a longer season than most other forage crops. Furthermore, it is rich in protein and mineral matter, it gives a heavy yield of forage, and it is very palatable.

BLUEGRASS PROVIDES EXCELLENT SPRING AND FALL PASTURE

Bluegrass furnishes cheap pasture for early spring and late fall, but it makes little growth in midsummer. Then such crops as alfalfa, clover, or rape should be provided.

Sows and Spring Litters on Rye Pasture

Winter rye provides excellent late fall and early spring pasture in the northern states. In the South fall-sown cereals furnish good forage from fall to spring. (From Wisconsin Station.)



Breeding Gilts Eating Alfalfa Hay from Rack

Legume hay is such an excellent feed for brood sows that it should always be furnished them when they are not on pasture.

required in dry lot. Manifestly, when an excess of supplement is thus fed, it does not have as high a value per ton as when wisely used.

Other trials show a similar advantage in supplying a supplement to pigs fed corn on alfalfa or clover pasture.[123]

But relatively few experiments have yet been carried on to determine just how much tankage or other supplement is needed to balance corn for pigs of various ages which are on good pasture. The trials available show that with pigs on such pasture as alfalfa, clover, or rape, only about half as large a proportion of supplement will be required as in dry lot feeding. For instance, pigs over 100 lbs. in weight on good pasture need only 5 lbs. of tankage or less to every 95 lbs. corn. In general, a safe rule is to feed about half as large a proportion of protein-rich supplement as it would take for pigs in dry lot to meet the requirements of the Morrison feeding standards. (Appendix Table V.)

Pigs on pasture which are self-fed, free choice, corn and in addition tankage, linseed meal, or wheat middlings, or else such mixtures as tankage and linseed meal, or tankage and corn germ meal, will generally balance their own rations fairly well. Sometimes they may take a little more supplement than is needed, but the saving in labor thru this method of feeding is sufficient to offset it. Pigs fed barley require much less supplement than those fed corn, but often pigs on pasture which are self-fed barley and tankage, free choice, will eat more tankage than if they had been fed corn. Therefore the ground barley and the supplement had best be mixed in proper proportions. Pigs over 100 lbs. in weight fed barley or wheat on good pasture need little or no supplement.[124]

985. Alfalfa pasture.—Wherever it thrives, alfalfa is the best permanent pasture crop for pigs. (340) It provides pasturage during a longer season than most other forage crops, starting early in the spring and remaining green and succulent in late summer when bluegrass has dried up and even clover grows hard and woody. Since the heavy pasturing of alfalfa is injurious to the stand, the number of pigs should be restricted and the plants allowed to grow up, being cut for hay 2 or 3 times a year. Except in the best alfalfa districts of the West, no more than 17 to 20 spring pigs per acre should usually be grazed on alfalfa, even when they are full-fed on concentrates in addition. If the amount of grain is limited, then less pigs should be carried per acre. Where the winters are severe, care must be taken not to pasture alfalfa too late in the fall, for there is danger of its being killed out unless sufficient growth is left standing to protect the plants. With pigs there is no danger from bloat on alfalfa pasture.

The following table summarizes the results of 8 trials in each of which one lot of spring pigs has been fed from early summer to market time

[123]Evvard, Iowa Bul. 136; Robison, Ohio Bul. 343; Snyder, Nebr. Bul. 165; Walker, Miss. Bul. 177; Waters et al., Kan. Bul. 192.

[124]Morrison and Bohstedt, Wis. Station, unpublished data.

on alfalfa pasture with proper proportions of corn and tankage in addition, and another lot has been similarly fed on rape pasture. The pigs averaged 49 lbs. in weight at the start and were fed for an average of 130 days:

Alfalfa vs. rape pasture for pigs

Average ration	Daily gain Lbs.	Concentrates for 100 lbs. gain	
		Corn Lbs.	Tankage Lbs.
*Lot I, alfalfa pasture**			
Corn, 4.5 lbs.			
Tankage, 0.26 lb. Alfalfa	1.24	362	21
*Lot II, rape pasture**			
Corn, 4.4 lbs.			
Tankage, 0.27 lb. Rape	1.20	359	22

*Average of 5 trials by Morrison and Bohstedt, Wis. Station (Unpublished data); and 3 by Evvard (Iowa Bul. 136, Cir. 53, and Am. Soc. Anim. Production, Proceedings, 1913).

The table shows that there was little difference in the results on alfalfa and rape pasture. The pigs on alfalfa pasture made a trifle more rapid gains than those on rape, but there was practically no difference in the amount of feed required for 100 lbs. gain. Furthermore, the average number of pigs carried per acre of pasture in these trials was nearly the same, being 19.9 pigs per acre for rape and 19.6 for alfalfa. Except where alfalfa thrives unusually well, rape will usually carry 3 to 4 more pigs per acre than can be grazed safely on alfalfa. In these trials the chief advantages in favor of alfalfa were that on the average 2,516 lbs. of hay was cut from the pasture plots, while none, of course, was secured from the rape plots. Futhermore, rape is not a legume, and does not add nitrogen to the soil. Also, it is an annual, and the cost of growing it is therefore somewhat higher than the cost of alfalfa pasture in sections where a seeding of alfalfa will last for 3 years or more.

As alfalfa is quite rich in protein and is high in calcium, pigs fed only corn on alfalfa pasture will make quite good gains, but it is ordinarily more economical to balance the ration by supplying a small amount of some protein-rich feed, such as dairy by-products, tankage, linseed meal, etc. (984)

986. Clover pasture.—In the northern and central states *red clover* is one of the most valuable pasture crops for pigs, being surpassed only by alfalfa and sometimes by rape. (348) Since early pasturing may kill clover, pigs should not be turned on until it has made a good growth. Clover does not furnish as constant a supply of succulent feed as does alfalfa, tending to become woody late in the summer, but clipping will greatly aid by inducing a new growth.

The following table summarizes the results of 5 trials at the Iowa and Wisconsin Stations in which clover and alfalfa pasture have been directly compared. In these trials spring pigs, averaging 51 lbs. in weight, were fed to market weights on either clover or alfalfa pasture with suitable proportions of corn and tankage in addition:

Clover vs. alfalfa pasture for pigs

Average ration	Daily gain Lbs.	Concentrates for 100 lbs. gain: Corn Lbs.	Tankage Lbs.
Lot I, clover pasture*			
Corn, 4.8 lbs. Tankage, 0.30 lb	1.30	372	23
Lot II, alfalfa pasture*			
Corn, 4.6 lbs. Tankage, 0.25 lb	1.25	370	20

*Average of 4 trials by Morrison and Bohstedt, Wis. Station (Unpublished data); and 1 by Evvard (Iowa Bul. 136).

In these trials the pigs on clover pasture made a trifle more rapid gains than those on alfalfa pasture, but required 2 lbs. more corn and 3 lbs. more tankage for 100 lbs. gain. Also, 280 lbs. more hay per acre was cut on the average from the alfalfa plots than from the clover pastures.

Red clover and rape have about equal rank as pasture crops for swine. Clover will furnish earlier pasture, but in midsummer the rape will usually furnish the best grazing. In 4 trials by Morrison and Bohstedt at the Wisconsin Station[125] and 1 by Evvard at the Iowa Station[126] in which clover and rape have been directly compared, pigs fed corn and tankage on clover pasture have gained 1.31 lbs. a head daily, and required 364 lbs. corn and 27 lbs. tankage for 100 lbs. gain. Others on rape pasture gained 1.25 lbs. a head daily and required the same amount of corn and 1 lb. less tankage for 100 lbs. gain. On the average 3.6 more pigs per acre were carried on the rape than on the clover, but on the other hand, an average of over 1 ton of hay per acre was furnished by the clover plots in addition to the pasturage. Furthermore, clover improves the soil, while rape does not. We may conclude that the choice between these two crops should be based on the adaptability of each to the local soil and climatic conditions. There is even more advantage in feeding pigs on clover pasture a protein-rich supplement in addition to corn, than there is in the case of alfalfa pasture, for clover is not so rich as alfalfa in protein.

Alsike clover is an excellent pasture crop on soils too wet or acid for red clover. (**350**) On sandy soil, *mammoth clover* may yield more pasture than red clover. (**349**) *White clover* is not commonly grown alone for pasture, but is important in mixed and native pastures in many districts. A mixture of white clover and bluegrass makes a much better pasture than bluegrass alone, especially in midsummer. (**351**) Particularly in the southeastern states, *crimson clover*, sown as a winter annual, furnishes valuable spring pasture for pigs. (**353**) *Lespedeza,* or Japan clover, is one of the most valuable pasture crops in the South. (**360**)

987. Sweet clover.—On soils not well adapted to alfalfa or red clover, sweet clover may often be used to advantage as a pasture for swine. (**352**) Experiments at various stations show that where they thrive, alfalfa and red clover are usually preferable to sweet clover.[127] Spring

[125]Unpublished data. [126]Iowa Bul. 136.

[127]Arnett and Joseph, Mont. Bul. 128; Evvard Iowa Bul. 136; Morrison and Bohstedt, Wis. Station, unpublished data; Peters and Geiken, N. D. Bul. 127; Rice and Laible, Ill. Station, information to the authors; Robison, Ohio Bul. 343.

sown biennial sweet clover can be pastured during the first summer and fall without much danger of injuring the stand. The second year it grows tall and woody, and the plants will usually die by midsummer if allowed to produce seed. The crop should therefore be pastured heavily early in the season and all tall growth should be cut for hay as soon as the plants begin to bloom. It is sometimes difficult to get swine to eat sweet clover, but they will usually become accustomed to it after a time.

988. Field peas for pasture.—Field peas or a mixture of field peas and oats are often grown for swine pasture in the northern states. (**355**) These crops provide excellent pasture for a short period, but can not compete with alfalfa, clover, or rape as long-season forages. By sowing rape with oats and peas, excellent pasture may usually be provided until late fall.

In certain districts of the Northwest where field peas thrive and grain is high in price, many pigs are fattened by allowing them to "hog down" field peas, into which they are turned as soon as the pods begin to ripen. Sometimes the pigs are confined to small plots by temporary fences or hurdles, so they will not waste the crop by trampling it down.

In trials during 3 years at the Idaho Station[128] with both spring pigs and fall pigs, Gongwer and Hickman found that on the average an acre of peas produced 406 lbs. of pork. The gains of the pigs were more rapid, but not any more economical, when the pigs were fed a limited amount of grain (rolled barley) in addition to the peas. Sometimes the unthreshed pea vines, after being stacked, are fed to pigs in yards.

989. Soybean pasture.—Soybeans are an important forage crop for swine in the South and also in sandy sections of the North. They do not furnish forage over a long season, as the pigs will often soon destroy the plants if turned into the field early in the season. Therefore, soybeans are usually grown, either alone or with corn, for fall feeding, and the pigs are turned in to hog down the crop after the seeds have begun to harden. As soybean seed is rich in protein, there is probably no advantage in feeding a protein-rich supplement to pigs hogging down soybeans, when they are fed corn in addition.[129] It is, however, usually profitable to feed a protein-rich supplement to pigs hogging down corn in which soybeans have been grown, since most of the feed then usually consists of the corn. (**942**)

In the South, soybeans are an excellent forage crop for fall, but in many sections are excelled by peanuts. For example, in 11 trials by Hostetler in North Carolina[130] pigs hogging down soybeans and fed a limited allowance of corn and shorts or tankage in addition gained 0.75 lb. a day and required 168 lbs. concentrates and 0.52 acre soybeans for 100 lbs. gain. Much poorer results were secured where no grain was fed in addition to the soybeans. In 3 trials by Gray, Ridgeway, and Eudaly in Alabama[131] pigs fed various proportions of corn on soybean pasture

[128]Idaho Bul. 125.

[129]Robison, Ohio Bul. 343.

[130]Information to the authors.

[131]Ala. Bul. 154.

gained on the average 1.15 lbs. a day and required only 127 lbs. corn and 0.18 acre soybeans for 100 lbs. gain. Where soybean pasture was used, pork was made for only 40 per ct. of the cost when corn was used alone without pasture.

Heavy feeding of soybeans produces soft pork, but the quality may be improved by finishing the pigs on corn with tankage, fish meal, cottonseed meal, or shorts after the grazing period on soybeans, as is discussed elsewhere. (**1005**)

990. Cowpea pasture.—Especially on the poorer soils in the southern states the cowpea is an important forage crop for swine, as it flourishes where other legumes will not produce good crops. (**357**) In a 60-day trial by Gray, Summers, and Shook in Alabama[132] pigs fed 1.56 lbs. corn per head daily on cowpea pasture gained 0.90 lb. daily and required only 173 lbs. corn and 0.83 acre cowpeas for 100 lbs. gain. Others fed corn and tankage in a dry lot gained only 0.54 lb. a day and required 540 lbs. concentrates for 100 lbs. gain. Peanuts and soybeans usually excel cowpeas for pigs on soil rich enough for their culture, for they produce more seed per acre. Like soybeans, cowpeas are often grown with corn for hogging down. Cowpeas are not a satisfactory forage crop for the northern states, as they are too late in maturing.

991. Velvet bean pasture.—In the South velvet beans are often grown with corn and the crop hogged down, part of the corn ears sometimes being picked first. The gains are usually satisfactory as long as the corn lasts, but then they are often poor. The velvet beans are not very palatable to pigs and furthermore, as has been pointed out before, raw velvet beans are not an efficient hog feed when forming the greater part of the ration. (**981**)

In an Alabama trial[133] pigs were turned into a field where velvet beans had been grown with corn, but the good corn ears had been already removed. In addition they were given a half ration of corn meal 9 parts, and tankage 1 part, while another lot was fed corn and tankage in a dry lot. The pigs foraging on velvet beans gained 1.23 lbs. a head daily and required 0.38 acre of beans and only 170 lbs. concentrates for 100 lbs. gain, while those in the dry lot consumed 400 lbs. concentrates per 100 lbs. gain.

992. Rape pasture; combinations including rape.—Over the greater part of the northern United States rape is the best single annual forage crop for swine. As it may be sown both early and late in the season, forage may be provided at any desired time. The best yields are usually obtained with spring seeding, and if the crop is not pastured too closely, growth will continue until severe frosts in the fall. Pigs should not be turned on the rape until it is 10 to 14 inches high. If rape is pastured heavily, the pigs must be removed when it has been grazed down to 4 or 5 leaves to the plant, in order to give the crop a chance to recover. A

[132] Ala. Bul. 168.

[133] Gray, Summers and Shook, Ala. Bul. 168.

better plan is not to overstock the pasture. If the pigs are full-fed concentrates on pasture, spring-sown rape on good soil should furnish good grazing thruout the season for 16 to 20 pigs, or even more per acre.

It has been pointed out previously that where alfalfa thrives, it slightly excels rape, chiefly because it need not be reseeded each year and also because it is a legume and thus builds up the soil. The portion of the rape plant eaten by pigs is nearly as rich in protein, on the dry matter basis, as is alfalfa. Therefore, pigs fed corn on rape pasture need no larger amounts of supplement than those on alfalfa pasture. (**984**)

White pigs and those with very thin hair or white belts or spots may blister if they run in rape when the sun is bright and the rape is wet with rain or dew. This sometimes occurs to a less extent on other forages. Blistering may usually be prevented by keeping such pigs out of wet rape on hot sunshiny days. However, the blistering is usually not serious in the northern states, even with white pigs. Care should be taken to rub crude oil, vaseline, or lard on any blistered spots.

Rape is an excellent winter forage crop for the South. In 2 trials at the Alabama Station[134] Gray, Summers, and Shook found that pigs fed a half allowance of corn and either shorts or tankage on rape pasture for 116 to 147 days during the winter, made an average daily gain of 0.70 lb. and required 0.14 acre of rape and only 273 lbs. of concentrates for 100 lbs. of gain.

In the extreme northern states, rape is often grown in combination with oats and peas or with only oats or barley. Where field peas thrive, in this section, oats-peas-and-rape pasture is usually slightly superior to rape alone. Pigs self-fed corn and tankage on oats-peas-and-rape pasture in trials by Morrison and Bohstedt during 5 years at the Wisconsin Station[135] gained no more rapidly than others on rape pasture, but each year they required a little less concentrates for 100 lbs. gain. On the average the saving amounted to 17 lbs. corn and 2 lbs. tankage for each 100 lbs. gain. This usually more than covered the additional cost of growing the mixture over seeding rape alone. Farther South, where field peas do not thrive as well, rape is equal or superior to oats-peas-and-rape.[136] In 2 trials at the Wisconsin Station a combination of oats-and-rape was slightly superior to rape alone, but on the other hand in trials at the Ohio and Pennsylvania Stations[137] rape alone was best.

993. Grasses and cereals for pasture.—Among the permanent grasses, *bluegrass* provides the best pasture thruout the northern states and forms the chief part of native pasture, often in combination with white clover. The cost per acre of bluegrass pasture is usually very low, for the pasture is permanent and areas not suited to cultivation can be used for the pasture. Bluegrass furnishes excellent early spring and late fall pasture, being ready even before alfalfa or the clovers. However, it makes little growth during midsummer, so other crops should be provided

[134]Ala. Bul. 168.

[135]Unpublished data.

[136]Evvard, Iowa Bul. 136; Grimes, Penn. Bul. 168.

[137]Robison, Ohio Bul. 343; Grimes, Penn. Bul. 168.

at this season. In 5 trials at the Iowa, Missouri and Wisconsin Stations[138] pigs on native pasture, consisting chiefly of bluegrass, gained as rapidly as others on rape pasture but required 21 lbs. more concentrates for each 100 lbs. gain. Furthermore, native pasture will not carry as many pigs per acre as rape. With pigs fed corn on bluegrass, a somewhat larger amount of protein-rich supplement is needed than on legume or rape pasture, tho very young bluegrass is fairly rich in protein. (**984**)

In the South *Bermuda grass* furnishes the best permanent pasture for pigs.

Winter rye provides excellent late fall and early spring pasture in the northern states, rivaling bluegrass in this regard. (**318**) Rye which is to be harvested for grain may be grazed lightly in the spring before the plants begin to shoot or joint. Sometimes *winter wheat* is used in place of rye. In the South fall-sown oats, rye, or wheat will furnish good pasture from fall to spring, greatly decreasing the cost of maintaining brood sows and raising fall pigs. If the swine are taken off early enough in the spring, considerable grain will be produced in addition.

Good of the Kentucky Station[139] found that green rye, wheat, and oats when 5 to 8 inches high are richer than well-grown alfalfa, clover, or cowpeas in protein. Hence the cereals at this stage are really nitrogenous pastures, and go far toward supplementing corn.

However, pigs fed a small amount of tankage or soy beans with corn on rye pasture made larger and more economical gains than those fed no supplement. During the periods when the pasture is covered by snow it is especially advantageous to feed a supplement with the corn.

994. Hogging down ripe grain.—Ripe grain, usually rye, bald barley, or wheat, is frequently hogged down, the pigs being turned into the field when the crop is nearly ripe. This practice is especially common in the grain districts of the Pacific Northwest, where the summers are dry. Hunter of the United States Department of Agriculture[140] reports that in eastern Washington 109 pigs hogged down 7.2 acres of standing wheat, having access to an acre of pasture in addition. From hogging the grain down, a net return of $15.73 per acre was realized. The net return from wheat alongside, harvested and threshed, was only $8.04 per acre.

In the corn belt and other humid districts hogging down rye has not proved to be a profitable practice compared with feeding pigs on such forages as alfalfa, clover or rape. In trials by Mumford and Weaver at the Missouri Station[141] the best results were secured when a limited amount of concentrates was fed to pigs hogging down rye, but even then other pasture crops returned much more profit. Similar results were secured in trials by Evvard and Robison.[142] In one trial Robison found

[138]Evvard, Iowa Station, Information to the authors; Morrison and Bohstedt, unpublished data; Weaver, Mo. Station, information to the authors.
[139]Ky. Bul. 175. [140]U. S. D. A. Farmers' Bul. 599. [141]Mo. Bul. 110.
[142]Iowa Bul. 136; Ohio, Mo. Bul. 42, and information to the authors.

that rye returned 77 cents more per bushel when harvested and fed to pigs, than when the crop was hogged down, tankage being fed as a supplement to both lots. As we have seen previously (**942**), hogging down corn is a most successful practice.

995. Gleaning stubble fields.—Especially on the grain farms of the West stubble fields are an important factor in economical pork production. Where the grain is harvested by means of a header a considerable amount is left ungarnered and was formerly wasted. Now many farmers are hog fencing their fields and turning pigs on the stubble to glean the scattered heads of grain. Gains made on such waste are almost clear profit.

996. Sorghum; Japanese cane.—Sorghum is too high in fiber to excel as a pasture for young pigs, tho it is useful in the South for providing succulence when other crops are not available. For older pigs it gives somewhat better results,[143] supplied in addition to a fair allowance of grain. (**309**)

Scott found at the Florida Station[144] that Japanese cane fed alone would not maintain young pigs. As succulence with grain this forage should have about the same value as sorghum. (**323**)

997. Soilage.—It is not ordinarily profitable to cut and haul green crops for pigs, for they can better do their own harvesting. If for any reason any of the hogs can not be provided with pasture, it will help to cut a little green feed for them, but it will save labor to fence off a paddock in some nearby field and turn them in. (**418**)

998. Roots.—Roots are highly esteemed by many swine raisers, especially for feeding brood sows. (**365-374**) In several trials carried on years ago roots were added to rations which were then considered satisfactory for pigs, but which we now know to be inefficient. For example, pigs were fed grain alone or grain and shorts alone in comparison with others fed roots in addition. In 8 trials[145] pigs fed concentrates alone gained 1.2 lbs. a head daily and required 499 lbs. concentrates for 100 lbs. gain. Others fed roots in addition (sugar beets in most of the trials) gained 1.0 lb. a head daily, and required 358 lbs. concentrates plus 631 lbs. roots for 100 lbs. gain. In these trials 448 lbs. of roots saved 100 lbs. of concentrates. If such a value as this could usually be secured from roots, when added to modern, efficient rations, they would without question often be economical winter feeds for swine, for with concentrates at $25.00 a ton, roots would be worth $5.50 a ton.

However, when roots have been added to efficient rations for brood sows or fattening pigs in trials by Morrison and Bohstedt at the Wisconsin Station,[146] the roots have had so low a value that they were decidedly

[143]Ala. Bul. 143; Fla. Bul. 113.

[144]Fla. Bul. 113.

[145]Average of 1 trial by Clark (Utah Bul. 101); 1 by Lazenby (Ohio Rpt., 1884); 2 by Plumb (Ind. Buls. 79, 82); 1 by Robertson (Ottawa Expt. Farms, Rpt. 1891); 2 by Sanborn (Utah Rpt. 1891), and 1 by Shaw (Mont. Bul. 27).

[146]Unpublished data.

uneconomical feeds. In these trials alfalfa or clover hay has been a much more efficient addition than roots to the rations of brood sows or fall pigs. (**1020**) We might expect this, since legume hay is rich in good quality protein, in calcium, and in fat-soluble vitamine, and it has a desirable laxative effect. Roots are palatable, succulent, and laxative, but are low in protein and in calcium. Moreover, most roots are low in fat-soluble vitamine, tho yellow carrots are rich in it. Roots should be chopped before being fed to swine.

Sometimes root crops may be economically gathered by turning pigs in to graze the field. At the Michigan Station,[147] Shaw turned pigs receiving one-third of a normal grain ration into a beet field to do their own foraging, and found that 1 acre of sugar beets produced 716 lbs. and 1 acre of half sugar beets and half mangels 792 lbs. of gain. In the South root crops may be advantageously used as forage for pigs during the winter.

999. Comparison of root crops.—The relative value of different root crops per ton depends primarily on their dry matter content. For example, in trials at the Danish (Copenhagen) Experiment Station[148] 4.0 lbs. sugar beets containing 21.2 per ct. dry matter equalled 1 lb. of ground barley, when fed in combination with skim milk, whey, and grain. With "fodder" beets containing 16.5 per ct. dry matter, it required 5.0 lbs. to equal 1 lb. of barley, and with mangels, containing 11.0 per ct. dry matter, it took 7.5 lbs. to replace a pound of barley. According to Day,[149] sugar beets not only possess the highest feeding value per ton, but are also most readily eaten by pigs. He states that hogs prefer mangels to carrots. (**367-72**)

1000. Wet beet pulp.—Wet beet pulp is not as commonly fed to swine as to cattle or sheep, but limited amounts may be successfully used. In a trial at the Utah Station,[150] 130-lb. pigs, fed 3.3 lbs. wheat shorts and 12.3 lbs. wet beet pulp a head daily, gained 1.2 lbs. per day and required 275 lbs. shorts and 1,030 lbs. beet pulp for 100 lbs. gain. Compared with pigs fed shorts alone, 609 lbs. of beet pulp replaced 100 lbs. of shorts. (**275**)

1001. Potatoes.—Marketable potatoes are usually worth too much to feed to hogs, but cull potatoes can be economically utilized for pork production. (**374**) They should preferably be cooked for swine and should be fed with concentrates. To balance the ration some protein-rich feed should be added, as potatoes have even a smaller proportion of protein than does corn. In 2 trials by Henry at the Wisconsin Station[151] 442 lbs. of potatoes fed after cooking equalled 100 lbs. of corn. At the Copenhagen (Denmark) Station[152] Fjord found 400 lbs. of cooked potatoes

[147] Mich. Bul. 233.
[148] Copenhagen (Denmark) Station, Rpt. 1892.
[149] Productive Swine Husbandry, p. 206.
[150] Utah Bul. 101.
[151] Wis. Rpt. 1890.
[152] Copenhagen (Denmark) Station, Rpt. 1890.

equal to 100 lbs. of mixed grain, and in trials by Fjeldsted and Potter in Oregon[153] it required 422 lbs. cooked potatoes to replace 100 lbs. of barley. Averaging together the results at these different stations, we may conclude that it will require about 420 lbs. of potatoes, fed after cooking, to equal 100 lbs. of corn or barley in feeding value. For the best results, the proportion of potatoes should not be greater than 4 lbs. of potatoes to 1 of concentrates. At the Oregon Station[154] Potter found potatoes fed raw were worth only about two-thirds as much per 100 lbs. as when fed after being cooked.

Potato silage, made by crushing potatoes with a special machine and adding 2 per ct. of corn meal to inoculate the silage with lactic acid bacteria, was worth less than half as much per 100 lbs. as cooked potatoes in a trial by Morrison and Bohstedt at the Wisconsin Station.[155]

1002. Artichokes.—Altho artichokes have long been grown in a small way and have often been extolled as a crop for pigs, their use by feeders does not seem to increase. Apparently this shows that they cannot compete with other crops. In trials at the Iowa Station Evvard[156] found artichokes less valuable than other forage crops. French of the Oregon Station[157] placed pigs in a field of artichokes, estimated to yield 740 bu. per acre. As the pigs made little gain on the tubers alone, a small allowance of mixed wheat and oats was supplied in addition, about 310 lbs. of mixed grain being then required to produce 100 lbs. of gain. In this case the artichokes saved from 150 to 200 lbs. of grain for each 100 lbs. of gain made. (**375**)

1003. Pumpkins; squashes.—Rommel,[158] summarizing the findings of 3 stations, reports that 273 lbs. of grain, together with 376 lbs. of raw pumpkins, gave 100 lbs. of gain with fattening pigs. When cooked it required 1,150 lbs. of pumpkins and 222 of grain for 100 lbs. of gain. From these data we may conclude that cooking is of no advantage with this vegetable. As has been pointed out before (**383**), the seeds should not be removed before feeding pumpkins, as they are rich in nutrients. Feeding an undue allowance of seeds would, however, tend to cause digestive disturbance, on account of their richness.

Cottrell[159] states that some Colorado stockmen have fattened hogs exclusively on raw squashes. They report favorable returns per acre, with meat of good flavor but having an undesirable yellow color.

1004. Sweet potatoes.—Dodson of the Louisiana Station[160] recommends sweet potatoes as the best root crop for pigs for fall and early winter grazing on the cut-over pine lands of the South. Sweet potatoes planted in June and early July are ready for feeding by the middle of October.

[153]Ore. Bul. 165.
[154]Breeder's Gaz., 63, 1913, p. 896.
[155]Unpublished data.
[156]Information to the authors.
[157]Ore. Bul. 54.
[158]U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[159]Colo. Bul. 146.
[160]La. Bul. 124.

Since the tubers are low in protein, pigs grazing sweet potatoes should be given such nitrogenous feeds as soybeans or cowpeas. Dodson states that an acre of sweet potatoes should carry 8 to 10 year-old pigs for 60 days, when they are given a limited concentrate allowance in addition. Duggar of the Alabama Station,[161] allowing pigs to harvest sweet potatoes at will, secured 100 lbs. of gain by feeding 313 lbs. of grain additional, thereby saving about 200 lbs. of grain for each 100 lbs. of increase while fattening. (376)

1005. Peanuts.—For the season in the fall when they are available peanuts provide one of the best forage crops for pigs in the South. (258, 362) Generally pigs are turned into the peanuts and allowed to gather the crop by rooting out the nuts. Usually Spanish peanuts have given larger yields of pork per acre than common or Virginia peanuts, which have larger nuts. Four trials by Hostetler in North Carolina[162] afford an example of the economical gains secured on peanut pasture. In these trials pigs fed corn alone or corn and shorts in addition to peanut pasture gained 1.25 lbs. a day on the average, and required only 104 lbs. corn and shorts plus 0.45 acre of peanuts for 100 lbs. gain. Compared with this, pigs fed similarly on soybean pasture gained only 0.74 lb. a day and required 187 lbs. corn and shorts plus 0.55 acre soybeans for 100 lbs. gain. The feed cost for 100 lbs. gain was less than three-fourths as much on peanuts as on soybeans.

In 2 trials by Templeton in Alabama[163] when pigs harvested a crop of peanuts they returned a net additional profit of $24.90 per acre over what the nuts and the hay would have brought on the market. In addition the labor of harvesting was saved. In one trial a crop yielding 39.5 bushels of peanuts per acre produced 668.2 lbs. pork, and in the other test a crop of 30.2 bushels per acre produced 416 lbs. of pork. On the average, 184 lbs. of peanuts, plus the forage furnished by the peanuts and any other vegetation in the field, produced 100 lbs. of pork. Peanuts can be grazed during only a relatively short season, for after a time the nuts will sprout or rot if left in the ground, especially in wet weather.

The only difficulty with peanuts for pork production, and that is a serious one, is that they produce a soft pork, which is discounted by the packers. This is due to the large proportion of olein, a liquid fat, in peanut oil. (126) By finishing the pigs on such concentrates as corn with tankage, fish meal, cottonseed meal, or shorts, after taking them from peanut pasture, the fat may be hardened, so the carcasses will be firm when chilled.[164] Statements have previously been made that the pork can be hardened satisfactorily by 4 to 6 weeks of such feeding, but recent investigations carried on by the United States Depart-

[161]Ala. Bul. 122.

[162]Information to the authors.

[163]Ala. Bul. 206.

[164]Ewing, Burk, et. al., Tex. Buls. 224, 226, 242; Scott, Fla. Buls. 157, 160; Templeton, Ala. Bul. 213.

ment of Agriculture in co-operation with southern experiment stations indicate that to secure carcasses that will be uniformly firm the pigs must be finished for 8 weeks or longer, after being taken off peanuts or soybeans.

1006. Chufas.—Like artichokes, the small tubers of the chufa remain in the ground uninjured all winter. Chufas grow best on light, sandy soils, producing 100 to 150 bushels per acre. Duggar at the Alabama Station[165] hurdled young pigs on a chufa field, giving them corn and cowpea meal additional. The average of 2 trials showed that, after due allowance was made for the grain fed, the chufas produced 307 lbs. of pork per acre. (**377**)

1007. Cassava.—At the Florida Station[166] Conner found that pigs fed cassava alone or equal parts of cassava and sweet potatoes did not maintain their weight. When fed with shorts cassava produced fair gains. Larger returns can generally be secured from other crops for pigs than from cassava. (**378**)

1008. Silage.—Alfalfa, clover, or other legume hay is much more satisfactory for pigs than silage of any kind. Corn silage is too woody and too low in digestible matter to be valuable for swine. If shotes and breeding stock live on a limited allowance of rich concentrates alone, they may suffer from lack of proper bulk in the ration. In such cases, if legume hay or roots are not available, even corn silage will be helpful in distending the digestive tract.

1009. Legume hay.—The high value of legume hay for swine has been emphasized previously in this and the preceding chapter. (**918, 939, 966**) Legume hay is rich in protein and this protein is of such a kind that it balances the proteins of the cereals quite efficiently, thus differing from the proteins of linseed meal, wheat middlings, gluten feed, and corn germ meal. Furthermore, legume hay is rich in calcium, and, at least if well cured, is high in the fat-soluble vitamine. An additional merit is that it is slightly laxative. The following chapter points out that, as a result of these virtues, no other feed aids more in keeping brood sows thrifty in winter and ensuring vigorous litters. Indeed, every farmer in the northern states should make a special effort to provide choice legume hay for his sows in winter, after the pasture season. (**1016**)

Young pigs can not utilize much alfalfa hay, for their digestive tracts are not suited to digest any large proportion of dry roughage, even good legume hay. Therefore, it is usually not economical to feed legume hay, even alfalfa, as the only supplement to corn for growing and fattening pigs. This is shown clearly by the trials reviewed in the following article. (**1010**) Legume hay has its highest value for pigs when added to a ration which might otherwise prove inefficient and produce poor results. For example, adding 5 per ct. of alfalfa hay to a ration of white corn and skim milk will prevent the pigs suffering from the lack of the fat-soluble vitamine in this ration. Also, at least for fall pigs in the

[165]Ala. Bul. 122.

[166]Fla. Bul. 90.

northern states after the pasture season, adding a little alfalfa hay to such a ration as corn and tankage will usually keep the pigs more thrifty and increase the profits. This is true even when yellow corn is fed. (939) Still better results have been secured in trials by Morrison and Fargo at the Wisconsin Station when both alfalfa hay and linseed meal have been added to corn and tankage. (966)

If pigs are forced to eat too much legume hay, then the gains are decreased and more feed is required for 100 lbs. gain. This is shown in 2 trials by Vestal at the Indiana Station[167] in which various percentages of alfalfa meal were added to a ration of corn and tankage for fattening pigs weighing about 100 lbs. at the start. All lots of pigs were carried to a uniform market weight on their respective rations, with the results averaged in the following table:

Adding alfalfa meal to corn and tankage for pigs

	Rations		Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I,	Corn and tankage		2.07	413
Lot II,	Alfalfa meal, 10.0 per ct.	Corn and tankage	2.07	424
Lot III,	Alfalfa meal, 18.5 per ct.	Corn and tankage	1.98	443
Lot IV,	Alfalfa meal, 27.0 per ct.	Corn and tankage	1.47	550

It will be noted that when 10 per ct. by weight of the ration consisted of alfalfa meal, the gain was the same as on corn and tankage alone, but a trifle more feed was required for 100 lbs. gain. Had only 5 per ct. of alfalfa hay been added to the ration, it is probable that the gains would have been more rapid than on corn and tankage alone, as is shown in the following article. (1010)

When the proportion of alfalfa meal was increased to 18.5 per ct. the gains were slightly decreased and 7 per ct. more feed was required for 100 lbs. gain than on corn and tankage alone. Including 27 per ct. of alfalfa meal in the ration, decidedly decreased the gains and increased the cost. The fiber content of this last mixture was 10 per ct., which is no higher than that of some mixed feeds sold for swine feeding. In these trials it was also found that when reground oat hulls were added to the corn and tankage ration in such a proportion as to bring the fiber content up to 10 per ct., the gains were made much smaller and more expensive. These trials show plainly that fattening pigs should not be forced to eat rations in which the fiber content is high, due to adding such low grade feeds as oat hulls, or a considerable amount of even such good roughage as alfalfa hay.

A simple method of supplying legume hay to swine is to feed it in a slatted rack. If the alfalfa hay is leafy and well cured, sows will usually eat enough of the hay when thus fed. However, pigs will often not eat much of any legume hay, even alfalfa, if it is fed uncut. If the pigs are being fed a ration which will be radically improved by getting them to

[167]Information to the authors.

eat 4 to 5 per ct. of legume hay, the hay should then be chopped and mixed with the concentrates. If this can not be done conveniently, the leaves and chaff which fall to the floor where the hay is pitched from the mow may be gathered up and mixed with the concentrates. With clover hay, which is much less palatable to swine than alfalfa, it may be necessary to use one of these methods even with brood sows.

1010. Alfalfa hay; alfalfa meal.—Leafy, bright *alfalfa hay* is the best of all legume hays for swine. Not only is this hay useful for brood sows but it is a cheap and fairly efficient supplement to corn or the other cereals for fattening pigs. While fattening cattle and sheep will consume enough alfalfa hay to make a well-balanced ration with corn, the fattening pig has not this capacity for roughage, and hence will not consume enough hay to balance his ration sufficiently to produce maximum gains. This is shown in the following table, which summarizes 5 trials in each of which one lot of pigs has been fed corn with alfalfa hay in racks, while another lot was fed corn and tankage:

Alfalfa hay vs. tankage as a supplement to corn

Average ration		Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Supplement Lbs.
Lot I,* Alfalfa hay, 0.84 lb.	Corn, 6.0 lbs.....	1.15	530	68
Lot II,* Tankage, 0.63 lb.	Corn, 6.3 lbs.....	1.50	421	41

*Average of 2 trials by Snyder (Nebr. Bul. 147); and 1 each by Gramlich and Jenkins (Nebr. Bul. 175); Griswold, Miss. Station (Information to the authors); and McCampbell (Kan. Cir. 78).

The pigs fed alfalfa hay and corn gained 1.15 lbs. a head daily, which was much better than if they had been fed corn alone, but was 0.35 lb. less than those fed corn and tankage. In each trial the pigs fed tankage as the supplement returned more profit than those fed alfalfa hay and corn. These trials show that unless protein-rich concentrates are unusually high in price compared with grain and alfalfa hay, it will usually prove most profitable not to use alfalfa hay as the only supplement to grain for fattening pigs. Alfalfa hay is most efficient as a supplement in fine winter weather when the pigs have good appetites for the hay and corn.

While alfalfa hay is not highly efficient, due to its bulky nature, as the only supplement to grain, adding 3 to 5 per ct. by weight of the hay to such a ration as corn and tankage improves it materially. This is shown in the following table, which summarizes the results of 2 trials by Gramlich and Jenkins at the Nebraska Station[168] and 3 by Morrison, Bohstedt, and Fargo at the Wisconsin Station.[169] In the Nebraska experiments one lot of 140-lb. pigs was self-fed corn and tankage, free choice, and another lot was fed in addition alfalfa hay in a rack. In the Wisconsin trials one lot of pigs, averaging 65 lbs., was self-fed a mixture of corn and tankage in proper proportions, while another lot was self-fed a mixture containing in addition 3 to 5 per ct. chopped alfalfa:

[168]Nebr. Bul. 175.

[169]Unpublished data.

Adding alfalfa hay to corn and tankage for pigs

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Tankage Lbs.	Alfalfa Lbs.
Lot I, no hay				
Tankage, 0.51 lb. Corn, 5.8 lbs.....	1.33	433	39	....
Lot II, fed alfalfa				
Alfalfa hay, 0.22 lb.				
Tankage, 0.54 lb. Corn, 5.8 lbs.....	1.44	402	38	16

The pigs fed alfalfa hay in addition to the well-balanced ration of corn and tankage gained 0.11 lb. more per head daily on the average. This increase in gain occurred in each of the trials, except one, and in that the gains for the two lots were the same. On the average, the pigs fed alfalfa hay required 16 lbs. less total feed for 100 lbs. gain than those receiving only corn and tankage. In these trials 100 lbs. alfalfa hay actually saved on the average 189 lbs. corn plus 8 lbs. tankage—a remarkable showing. These results were due to the fact that, for some reason or other, adding a little alfalfa hay makes a ration of corn and tankage more efficient for pigs in dry lot, provided too much hay is not included in the ration. Just what this favorable effect is due to is still a problem. Possibly the combination of proteins is made more efficient for growth, or the effect may be due to increasing the amount of fat-soluble vitamine in the ration.

When swine eat sufficient uncut alfalfa hay from suitable racks, there is little or no advantage in chopping it or grinding it to a meal.[170] However, it is often difficult to get swine, especially pigs, to eat enough hay to be of any material advantage unless it is thus prepared or unless the leaves and chaff are fed. Hay chopped by running it thru a feed cutter, equipped with an alfalfa screen, is entirely satisfactory for swine, and this is an inexpensive method of preparation, compared with grinding to a meal.

1011. Clover hay; hay from other legumes.—Red clover hay is not nearly as palatable to swine as alfalfa hay, and furthermore is not as rich in protein or in lime. Therefore it falls materially below alfalfa in feeding value for this class of stock. On soils not adapted to alfalfa, clover is, however, a helpful substitute.[171] By mixing chopped clover hay or clover chaff with ground concentrates the sows or pigs will readily eat enough to aid in keeping them thrifty. Sometimes brood sows may eat sufficient uncut clover hay, fed in a rack, if it is leafy and of choice quality.

As yet there is little definite information concerning the relative values of hay from other legumes for swine. When alfalfa is not available, hay from soybeans, cowpeas, lespedeza, and sweet clover should be helpful substitutes.

[170] Snyder, Nebr. Bul. 124.
[171] Linfield, Mont. Bul. 57.

CHAPTER XXXV

FEED AND CARE OF SWINE

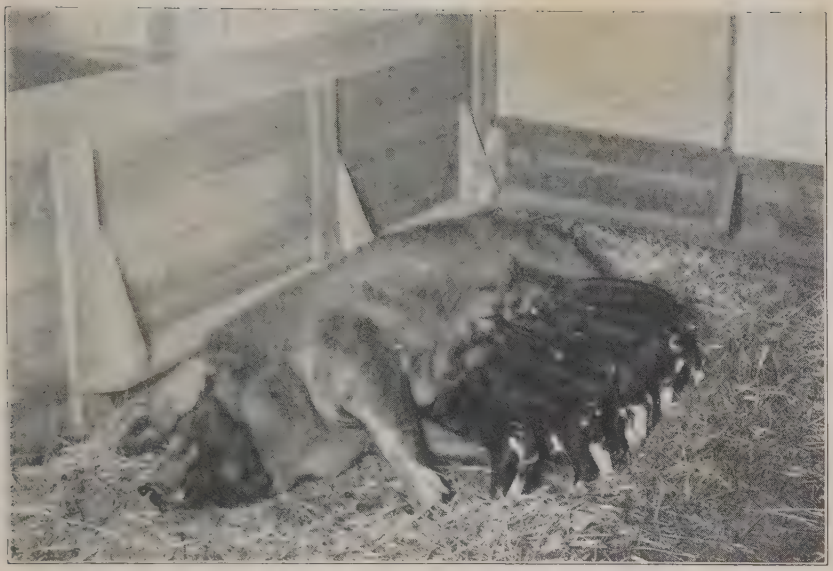
Due primarily to the economy with which it produces meat, the hog is found on far more American farms than are either beef cattle or sheep. On the well organized general farm, hogs utilize the household garbage and any dairy by-products, as well as saving the waste in the grain fields. On dairy farms, except where whole milk is sold, pork production must be an important farm enterprise, if full value is to be realized from the skim milk, buttermilk, or whey. On beef farms, the hog occupies a no less important place, for much of the profit in cattle fattening comes from the pork produced by the pigs following the fattening steers.

In some sections of the country, especially in the cotton belt of the South, the merits of the hog are not yet fully appreciated, and farmers often raise no pork, even for themselves, but buy it at considerable expense on the local market. On an efficiently managed farm, usually enough pigs can be raised at a minimum of expense to provide the pork for the family.

In the economy with which he converts the gross products of the farm into meat the pig excels all other farm animals. Garbage, vegetable and other waste, green forage, and grain are all voraciously consumed and quickly and economically converted into flesh. So swift is his career that he usually breaks into life with the spring flowers, plays the gormand in summer, and yields his unctuous body a sacrifice to men's necessities with the dropping of the leaves in fall. The pig is the poor man's reliance and the opulent farmer's gold mine. Of all domestic animals he is the most prolific, and his possibilities in multiplying are the delight of the city man in his ecstatic dreams of land owning and raising his meager investment in a single mother pig to the *n*th power thru her precocious progeny.

1012. Essentials in feed and care of brood sows.—In securing a good profit from hogs nothing is of greater importance than proper feed and care for the brood sows and boars. Each year thousands of farmers are grievously disappointed at farrowing time by seeing their possible profits vanish when their sows produce unsatisfactory litters. Either the litters are small or the pigs are so weak that they die, or survive only to be unprofitable runts. In most cases such results are due to a lack of proper feed and care for the sows. Yet the needs of brood sows are relatively simple and easily met.

The most important points in the feeding and care of brood sows are: (1) well-balanced rations, which will furnish plenty of protein, and



FARROWING PEN EQUIPPED WITH FENDERS

Every farrowing pen should be supplied with fenders to prevent the sow from crushing the little pigs against the wall or lying on them. See Page 696. (From Wisconsin Station.)

YOUNG PIGS FEEDING IN A CREEP

It is important to supply young pigs feed in addition to their mother's milk after they are 2 to 3 weeks old. (From Wisconsin Station.)

EVERY LITTER NEEDS GOOD PASTURE

Nothing is more important in swine raising than furnishing good pasture just as early as possible for the brood sows and their litters.

BREAKING OFF THE "WOLF" TEETH

Commonly the most experienced breeders break off the "wolf" teeth, or temporary tusks, which pigs have at birth, to prevent lacerating the udder of the sow or wounding the other pigs. See Page 697. (From Wisconsin Station.)

moreover, protein that is well-balanced in composition; also, the rations must supply ample mineral matter and sufficient vitamines; (2) rations which are laxative, instead of constipating; (3) the right amount of feed—not too much or the sows will get too fat; (4) plenty of exercise; (5) comfortable quarters—dry, roomy, well-ventilated, and well lighted; (6) freedom from worms and lice.

1013. Well-balanced rations necessary.—The pregnant sow needs a ration containing liberal amounts of protein and mineral matter, especially calcium and phosphorus. This is because considerable amounts of these nutrients are needed in the development of the unborn young, in addition to the supply required for the nourishment of the sow herself. When sows are nursing their litters, there is a still greater need of these nutrients, for milk is rich both in protein and in mineral matter. (**147-150**) Young sows need a larger proportion of protein and mineral matter than mature sows, in order to provide for the growth of their own bodies. In this connection it is important to bear in mind that a large proportion of each year's pig crop is borne by young gilts only about a year of age.

Not only must sows receive an ample quantity of protein, but also the protein in the food must be well-balanced in composition. (**915**) As has been pointed out previously, the quality of the proteins in the ration is a matter of far greater importance in feeding swine than with cattle or sheep. This is because swine are fed chiefly on the grains and grain by-products, all of which contain poorly balanced proteins. For instance, good results are not secured if sows, when not on pasture, are fed such a combination as corn with gluten feed (a corn by-product), even if mineral supplements are added to the ration. (**980**) Without question, brood sows also need supplies of the fat-soluble vitamine and of the water-soluble vitamine. All ordinary rations contain plenty of the latter, but there may sometimes be a lack of the fat-soluble vitamine, especially if white corn is fed as the grain. (**939**)

1014. Grain alone unsatisfactory for sows.—Many farmers have learned to their sorrow a fact clearly shown by scientific experiments—that grain alone is an entirely unsatisfactory winter ration for brood sows. Not only are the grains low in protein, but they are also very deficient in calcium, and the proteins are of an unbalanced nature. Furthermore, with the exception of yellow corn, the common grains are low in the fat-soluble vitamine. On such a ration sows can not be expected to produce large and thrifty litters. In a trial by Evvard at the Iowa Station[1] the average weight at birth of pigs from gilts fed only ear corn in winter was but 1.74 lbs. and only 68 per ct. of the pigs were strong. Compared with this unsatisfactory record, the pigs from gilts fed ear corn with tankage, alfalfa hay, or clover hay to supplement it, averaged 2.18 lbs. in weight and 92 per ct. of them were strong. In a similar trial with yearling sows, the pigs from sows fed corn alone weighed 1.85 lbs. on the average and but 41 per ct. of them were strong. On tankage and ear

[1]Am. Soc. Anim. Production, Proceedings 1913.

corn, the pigs averaged 2.42 lbs. and 85 per ct. were strong. The pigs from the sows fed corn alone also had smaller bones than those from the dams fed corn and tankage.

In similar trials by Vestal at the Kansas Station[2] the results were even poorer on corn alone. One sow on this inadequate ration died a month after farrowing, another became paralyzed, and a third had only one pig.

1015. Suitable supplements for sows.—Protein-rich feeds of animal origin and choice legume hay stand in a class by themselves as excellent supplements to the grains for brood sows not on pasture, just as they do for growing pigs. Skim milk, buttermilk, tankage, and fish meal are not only rich in well-balanced protein, but are also high in calcium and phosphorus. The legume hays do not supply quite as efficient proteins as these animal feeds, but they are rich in lime and in addition have a laxative effect and give bulk to the ration. Combinations of grain and legume hay, along with small amounts of dairy by-products or other feeds of animal origin, make ideal winter rations for brood sows. Grain and such feeds as wheat middlings, wheat bran, and linseed meal also are satisfactory combinations, if the sows have legume hay or are in sections far enough south so that some pasturage can be provided during the winter.

In nutrition experiments by Hart and Steenbock of the Wisconsin Station[3] sows were maintained for months on corn, oats, or barley, supplemented by only such protein-rich feeds as linseed meal, wheat middlings, or field peas, and with salt in addition and water quite high in calcium to drink. On such rations the offspring tended to be small and weak, and when sows were kept on such feeds for successive gestation periods many of the pigs were born dead. Even when ground rock phosphate was added to a ration of yellow corn, linseed meal, and salt, to supply more calcium, the results were still poor. However, when 15 to 25 per ct. of alfalfa hay was included in the ration, normal litters were produced.

1016. Legume hay.—Legume hay excels in so many respects as a feed for pregnant sows, and furthermore is so economical, that a special effort should be made always to supply it in winter when the sows are not on pasture. When choice, leafy alfalfa hay is available, the sows will usually eat a sufficient amount to produce the desired results if it is fed uncut in a simple slatted rack, preferably with a cover to keep out snow and rain. This, together with the feed troughs, should be put in the paddock at some distance from the hog house or cot, so the sows will secure needed exercise in going to and fro. Clover hay is usually less palatable to sows than alfalfa, and consequently they will often eat relatively little of it when fed uncut in a rack, even if the allowance of concentrates is restricted. Whenever the sows fail to eat enough of the legume hay, it

[2]Kan. Rpt. 1916–17, p. 14.

[3]Wis. Buls. 323, pp. 16–17; 339, pp. 121–3; Jour. Biol. Chem., 39, 1919, pp. 209–233.

should, if possible, be cut or chopped and mixed with the concentrates. The hay may be chopped at small expense by running it thru a feed cutter, preferably equipped with an alfalfa screen. If no cutter is available, the leaves and chaff which accumulate where the hay is pitched from the mow may be gathered up and mixed with the concentrates. To get the sows to clean up such chaff it may be necessary to feed the mixture as a slop. A safe rule is to see that legume hay forms at least 8 to 10 per ct. of the ration for sows in winter and they may well be fed all they will eat in addition to a limited allowance of grain.

But little study has been given to the relative value of the different kinds of legume hay for brood sows. In general it appears that the value will depend on the leafiness and palatability. Alfalfa hay excels clover, because it is richer in both protein and lime, as well as being liked better by swine. Dvorachek found soybean hay and cowpea hay satisfactory for brood sows in a trial at the Arkansas Station,[4] tho they wasted more of these hays than they did of alfalfa.

Mature sows are sometimes wintered on alfalfa hay without any grain or other concentrates, but this is inadvisable, for they will not make the desired gains in weight during pregnancy. Also, tho the cost for feed up to farrowing time will be low, experiments by Grimes at the Pennsylvania Station[5] show that it will then be necessary to feed them with great liberality on concentrates to provide even a fair milk flow for their pigs. This will offset the saving in concentrates before farrowing.

A ration of only legume hay and grain is quite satisfactory for brood sows, especially for yearlings or older sows.[6] Gilts had best receive a small amount of a protein-rich concentrate in addition, such as tankage, skim milk, buttermilk, linseed meal, or wheat middlings. This is shown by trials during 4 winters by Morrison and Bohstedt at the Wisconsin Station.[7] Each winter one lot of gilts averaging 206 lbs. in weight at the start was allowed access to good alfalfa hay in a rack and fed in addition enough ear corn to make the desired gains. Another lot was fed similarly except that they were given in addition one-quarter to one-third pound of tankage per head daily, as shown in the following table:

Alfalfa hay as only supplement vs. alfalfa plus tankage

	Daily gain	No. of pigs farrowed	Av. wt. of pigs	Proportion of vigorous pigs	Feed cost per head daily
	Lbs.		Lbs.	Per ct.	Cents
Lot I					
Alfalfa hay, 0.50 lb.					
Ear corn, 5.2 lbs*	0.93	7.12	2.25	80.8	5.6
Lot II					
Tankage, 0.30 lb.					
Alfalfa hay, 0.48 lb.					
Ear corn, 4.7 lbs.*	1.00	7.90	2.34	89.2	5.5**

*Ear corn reduced to basis of No. 3 shelled corn.
**Crediting excess gain of Lot II over Lot I at 7 cts. per lb.

[4]Information to the authors.

[5]Penn. Bul. 168.

[6]Evvard, Am. Soc. Anim. Production, Proceedings 1913; Grimes, Penn. Bul. 168; Snyder, Nebr. Bul. 147.

[7]Wis. Bul. 302, pp. 62–3; unpublished data.

On the average the gilts fed 0.3 lb. tankage in addition to ear corn and alfalfa hay made somewhat larger gains. Also the average weight of the pigs at birth and the proportion of vigorous pigs were greater with this ration. When the additional gains of the gilts fed tankage are credited at 7 cents per lb., the feed cost per head daily was also a little less on this ration, with ear corn at 56 cents a bushel and with tankage at $60 and alfalfa hay at $15 a ton. Thus from all standpoints it was advisable under corn-belt conditions to add a small amount of a protein-rich concentrate to the ration of corn and alfalfa hay. In trials by Robison at the Ohio Station[8] with old sows, adding tankage to corn and clover or alfalfa hay was also beneficial. When alfalfa hay is of excellent quality, old sows will generally eat a pound a day or more, if the allowance of corn is strictly limited. There may then be no appreciable advantage in adding any other supplement.

If sows will eat a reasonable amount of legume hay when it is fed uncut in a rack, there is no advantage in chopping or grinding the hay and mixing it with the grain in order to get them to consume a larger proportion of hay. Snyder[9] found even under conditions in western Nebraska, where alfalfa is cheap, that the cost of wintering brood sows fed a mixture of half ground corn and half chopped alfalfa was greater than for sows fed shelled corn with alfalfa hay in racks.

1017. Tankage versus tankage and legume hay.—Often the recommendation is made that brood sows be fed grain supplemented by only about 10 per ct. of high-grade tankage in the case of gilts or 6 to 7 per ct. in the case of older sows. Such a ration will usually give quite satisfactory results, but it lacks bulk and the sows will not be as well satisfied as tho there were added some legume hay or, if this is not available, some other bulky feed like wheat bran or oats. In one trial at the Wisconsin Station by Morrison and Bohstedt[10] the pigs from gilts fed only ear corn and tankage were not quite so vigorous as from others fed alfalfa hay in addition. Especially since legume hay is usually cheaper than grain, it is wise to add it to all such rations.

1018. Dairy by-products; other supplements.—If skim milk or buttermilk are available for the sows, there is no better ration than grain and legume hay, plus 4 to 6 lbs. of either of these dairy by-products per head daily. There is no need whatsoever in adding any purchased concentrates to such a ration, unless perhaps a little wheat bran or linseed meal shortly before farrowing, to ensure the sows being kept in a laxative condition.

Whey is relatively low in protein, but nevertheless the protein it does contain is of such high efficiency that a ration of grain, legume hay, and whey will be found satisfactory for sows. If legume hay is not fed, a small amount of a feed like linseed meal, wheat middlings, or wheat bran should be added to a ration of grain and whey, especially if the grain is corn.

[8]Ohio Mo. Bul. 48. [9]Nebr. Bul. 147. [10]Unpublished data.

As has been stated before, rations of only grain and such feeds as linseed meal, wheat middlings, wheat bran, or gluten feed are not ideal for brood sows. (1013) Where the sows have been on first-class pasture during the summer and have plenty of exercise in winter, such rations will in many cases give satisfactory results, especially if a mineral supplement is added to supply calcium, which is low in all these feeds. However, for both safety and economy, it seems a much wiser plan to supply legume hay in addition, or else add a small amount of dairy by-products, tankage, or fish meal to the ration.

1019. Grains for brood sows.—On account of its cheapness, corn is the chief grain fed to sows thruout the corn belt. Due undoubtedly to the poor results secured when corn is unwisely fed to brood sows without proper protein-rich supplements, several writers have gone so far as to state that corn should not form over one-third to one-half the ration for brood sows, as it is "too fattening." However, recent trials have shown clearly that excellent results are secured when corn is the only grain, if it is properly supplemented and provided the allowance is strictly limited to the amount needed to keep the sows in thrifty condition, without becoming too fat. In 3 trials with gilts at the Wisconsin Station by Morrison and Bohstedt[11] a concentrate mixture which many breeders would consider about ideal was compared with the more simple ration of ear corn, alfalfa hay fed in a rack, and 0.3 lb. tankage per head daily in addition. The concentrate mixture consisted of 35 parts ground corn, 30 parts ground oats, 30 parts wheat middlings, and 5 parts tankage. On the average, the gilts required 5.5 lbs. of this mixture per head daily to keep them making the desired gain of about 0.9 lb., while the other lot made a trifle larger gains on 4.5 lbs. corn (reduced to the basis of shelled corn), 0.3 lb. tankage, and 0.4 lb. alfalfa hay. Thus the gilts fed ear corn properly supplemented required 0.3 lb. less feed per head daily, which would be expected from the fact that corn is a more concentrated feed and richer in net energy than oats or middlings. With feeds at usual corn belt prices, the daily cost of feed per sow was 30 per ct. less on this ration. Still more important was the fact that the farrowing results were even a trifle better than on the ration which contained only 35 per ct. of corn. In 2 trials by Grimes at the Pennsylvania Station[12] a mixture of equal parts of corn, oats, and middlings was no better and was more expensive than a ration of corn and tankage or one of corn and alfalfa hay. Sometimes, as has been pointed out, such a mixture as this, fed without legume hay, will give poor results, as it is low in calcium, and furthermore, the protein is not well balanced. (118)

Where other cereals are cheaper than corn, pound for pound, they may often be used economically for brood sows, but none, with the possible exception of ground wheat, is equal to corn in feeding value. In a trial with gilts at the Iowa Station[13] Evvard found ground barley, fed

[11]Wis. Bul. 302, pp. 62–3; unpublished data.

[12]Penn. Bul. 168.

[13]Information to the authors.

dry, worth about 95 per ct. as much as shelled corn per pound, when fed with a small amount of tankage and ground alfalfa. Dry whole barley or soaked whole barley was worth only about 80 per ct. as much as shelled corn. Ground oats is an excellent feed for brood sows, as it is richer in protein than corn and is bulkier, but it is worth less per pound than corn, and therefore in the corn-belt is not usually as economical as that grain. The grain sorghums are all very satisfactory feeds for sows, when rightly supplemented, just as is necessary with corn.

1020. Succulent feeds for brood sows.—Without any question, roots are a desirable addition to the ration of the brood sow when no legume hay is fed, for they are palatable, bulky, and laxative. However, they are not rich in protein and calcium, as is legume hay.

To find whether there was any advantage in adding roots to well-balanced rations including alfalfa or clover hay, Morrison, Bohstedt, and Fargo conducted experiments during 4 winters at the Wisconsin Station.[14] Either sugar-mangels or yellow carrots were added to a ration of corn, tankage, and alfalfa hay or a ration consisting of clover hay and a concentrate mixture of barley, oats, wheat middlings, and linseed meal. Gilts, yearlings, and aged sows were used in the various trials. Contrary to what many experienced swine breeders would predict, in no case did the addition of roots to these rations result in larger or more thrifty pigs. Furthermore, roots proved to be decidedly uneconomical under corn belt conditions, for in no case was their actual feeding value as high as $4.00 per ton with corn at 56 cts. a bushel and other feeds at corresponding prices.

In a trial by Joseph at the Montana Station[15] sugar beets were worth slightly less than half as much as alfalfa hay when sows were fed hulless barley and either sugar beets or hay.

Silage is not a very satisfactory feed for brood sows, for they will usually eat only the corn grain, leaving most of the forage. In most parts of the country, legume hay is far more economical and also more satisfactory than roots or silage.

1021. Amount of concentrates to feed pregnant sows.—It is just as important not to over-feed pregnant sows as it is to feed them a well-balanced ration. If they become too fat, they are apt to have weak pigs, be restless and clumsy at farrowing time and then kill their pigs, and also be poor milkers. On the other hand, a sow which is too thin lacks the reserve energy necessary to nourish her pigs properly before and after birth. A mature sow which is in thin, active condition at the beginning of the breeding season in the fall should be fed so as to gain 75 to 85 lbs. by farrowing time in the spring. This will about cover the loss in weight which will occur at farrowing and while she is nursing her pigs. More of this gain should be made during the last 4 to 6 weeks of the gestation period than during the first part, for most of the growth of the litter occurs then. If mature sows are fed plenty of legume hay, about

[14]Unpublished data. [15]Information to the authors.

0.8 to 1 lb. of concentrates daily per 100 lbs. of live weight will be sufficient during the first 10 to 12 weeks, and from 1.2 to 1.3 lbs. during the last 4 to 6 weeks of the gestation period.[16] As sows will eat much more feed than this if it is supplied, and will usually squeal lustily for a more liberal allowance, one must not pay any attention to their desires, but feed only enough to keep them at the proper weights and in the desired condition. It pleases an experienced hog raiser to see his sows industriously hunting for the last grains of corn, for he knows that they are securing the exercise which is so essential for a good pig crop. Furthermore, he knows that his feed bill will be much less than if he had allowed mistaken generosity to rule in feeding the sows.

Yearlings and especially gilts should receive more concentrates in proportion to their live weight, in order to provide for their growth. As a rule an average allowance of 1.4 to 1.6 lbs. concentrates daily per 100 lbs. live weight in addition to legume hay will be plenty for yearlings, and 1.6 to 1.7 lbs. daily per 100 lbs. live weight for gilts.

1022. Methods of feeding brood sows.—The use of self-feeders for brood sows is sometimes advocated, and without question this method may be used successfully if great care is taken to feed a suitable mixture which includes just enough chopped legume hay so that the sows will not, on the one hand, become too fat, or on the other hand, fail to make the desired gains. To regulate the mixture properly takes considerable experience as well as much care and bother. In 3 trials at the Wisconsin Station by Morrison and Bohstedt[17] feeding gilts ear corn with a little tankage and with alfalfa hay in a rack proved decidedly preferable to self-feeding a mixture of chopped alfalfa and ground corn, with tankage self-fed separately. The sows did not over-eat on tankage, but there was much difficulty in shifting the proportions of alfalfa and corn to keep them in the desired condition. As a rule 30 to 40 per ct. of the mixture consisted of chopped alfalfa. For older sows the proportion of hay should be larger.

In trials by Snyder at the North Platte, Nebraska, Substation,[18] mature sows were successfully wintered by self-feeding a mixture of 3 parts by weight of chopped alfalfa hay and 1 part of ground corn.

Occasionally self-feeding ground oats to sows is recommended, but in a trial at the Wisconsin Station gilts self-fed a mixture of 75 parts ground oats, 23 parts standard middlings, and 2 parts tankage became entirely too fat and produced unsatisfactory litters.

Many writers recommend feeding brood sows their concentrates in the form of a slop. In certain cases there may be some advantage in this. For example, sometimes sows waste quite a little of a fine concentrate mixture fed in a trough. This may be avoided by slop feeding. Also in very cold weather sows can be forced to take more water than they otherwise would by feeding a slop with the chill taken off. However, if

[16]Smith, Pork Production; Robison, Ohio Monthly Bul. 48.
[17]Unpublished data. [18]Nebr. Bul. 162.

a heated automatic waterer is provided, feeding warm slop is probably not worth the added trouble, even in the northern states. More and more are hog raisers giving up the slop barrel, which often becomes a filthy method of feeding swine. (923)

It is not a good plan to allow pregnant sows, especially those heavy in pig, to follow fattening cattle. They are apt to become too fat and also to be injured by the cattle.

1023. Water; salt, and other mineral supplements.—Plenty of clean fresh water should always be furnished brood sows, and the supply should be conveniently accessible so they will take enough for their body requirements. In winter thruout the northern states it is wise to provide a heated automatic waterer. Many men foolishly make no other provision for watering their sows than to pour cold water into a colder trough once or perhaps twice a day. Often the water freezes over in a little while, and for the rest of the day the thirst of the sows must be unsatisfied.

Brood sows should always be supplied with salt. This had best be fed in a suitable box or self-feeder, so they can take what they wish.

Whether it will be beneficial to add other mineral supplements, will depend on the ration fed. With good legume hay and such animal feeds as dairy by-products, tankage, or fish meal, there is generally no need of any mineral except common salt. If there has been trouble from hairless pigs, iodine should be supplied, as is pointed out elsewhere. (917) When rations are fed which are low in calcium or phosphorus, mineral supplements should be added which furnish these essentials. This matter is discussed fully in preceding chapters, and it is pointed out that there is no evidence whatsoever that better results are secured by feeding expensive proprietary mineral mixtures than by using the simple mixtures there recommended. (99, 916)

1024. Exercise; shelter.—An abundance of exercise for the pregnant sows is absolutely indispensable if thrifty pigs are to be expected. To force the sows to take plenty of exercise, it is a good plan to feed them at a point quite a long ways from their sleeping quarters. If there is at this place a rack with choice legume hay, the sows will make many trips back and forth each day. When sows are fed ear corn and the allowance is properly limited, they will spend considerable time searching for the last kernels, and the longer they can be kept on their feet, the better it is for their health. If a ground concentrate mixture is fed, it is often a good plan to scatter a little shelled corn, whole oats, or sheaf oats on the ground for them to work over. Sows heavy in pig should not be compelled to plow thru snowdrifts, but paths should be made for them. Ashes or litter, such as straw, should be put on icy places, else they may slip and wrench themselves, which may result in abortion.

Shelter for swine is discussed in a preceding chapter. (931) It is there pointed out that the prime essentials are that winter quarters be dry, well-lighted and well-ventilated, but free from drafts. There should be sufficient room so that the sows can keep their beds clean and

can sleep without piling up, else those at the bottom will become overheated and contract colds readily.

1025. Summer care of brood sows.—If plenty of good pasture is provided, the problem of feeding brood sows in summer after the spring litters are weaned is easily solved. Where sows raise but one litter of pigs a year, they need little or no concentrates in summer, if they are on such first class pasture as alfalfa, clover, or rape. Enough grain should be fed to keep the sows in thrifty condition, and in any event they should get some grain for two or three weeks before breeding time in the fall. (1026) On such protein-rich pasture the concentrates should be mostly carbonaceous in character, such as corn, wheat, barley, kafir, or milo, with a small amount of some protein-rich supplement to balance the ration. For example, dry sows on alfalfa, clover, or rape pasture will do well on corn with no more than 4 to 5 per ct. by weight of tankage, or on equal weights of corn and either skim milk or buttermilk. When barley, oats, or wheat is supplied, little, if any, supplement is needed when the pasture is first class.

Where sows raise two litters a year, they will need more concentrates in addition to pasture, due to the added draft on their bodies. They should be fed so as to make about the same gains as recommended for sows in winter. (1021)

1026. The sows at breeding time.—Sows are in the best condition for breeding when they are in thin flesh but gaining in weight. If their litters have just recently been weaned, or if the sows have been carried thru the summer on good pasture and only a little concentrates, they will be in ideal condition to prepare for the breeding season. About two weeks before breeding starts, the sows should be "flushed," just as in the case of ewes. (879) This consists in increasing their feed so they will gain from one-half to three-fourths of a pound a day. Sows thus treated are more apt to have large litters, and they also come in heat more promptly and are more likely to become pregnant from the first breeding. The ration at this time should contain some protein-rich feed and be very similar to the ration fed during the gestation period. If possible, the sows should always be on good pasture at this season.

If only a few sows which are of about the same size as the boar are to be bred and furthermore if they are not to be bred for early litters, the boar may be turned with the sows and allowed to breed them as they come in heat. In a large herd or when the sows are to farrow early in the spring, hand-coupling must be practiced. This conserves the boar's energies and permits recording the breeding date, so that in the spring the sow may be properly cared for when she is due to farrow. When hand-coupling is practiced, a vigorous mature boar can be expected to take care of a maximum of 30 sows, if the services are well distributed.

1027. The boar.—The feed and care of the boar do not differ materially from that of the sows. He should be kept in thrifty condition, neither too fat nor run down in flesh, as either extreme may injure his

breeding powers. In summer the boar should run in a pasture lot, and in winter he should have the freedom of a small yard adjoining the pen. About 1 lb. or less of concentrates daily per 100 lbs. live weight is sufficient in summer for fairly mature boars on good pasture. During service the boar requires more feed than at other seasons. In winter mature boars should be given only enough concentrates to maintain their weights. Young boars need enough concentrates to keep them growing thriftily.

The most common mistake made in feeding boars is to overfeed them and allow them to become so fat that their breeding powers are seriously injured. Two weeks before the breeding season begins, the ration should be increased somewhat, so the boar will be gaining in weight when service begins. The amount of concentrates to be fed during the breeding season will depend on how much the boar is used. In general he should be fed enough to prevent his losing much weight. Many breeders prefer not to feed much corn to boars during this time and use concentrate mixtures made up of farm grains and a considerable proportion of protein feeds, such as wheat middlings or bran, linseed meal, tankage, and chopped legume hay.

1028. Gestation period; breeding studies.—It has been generally stated that the average gestation period of sows is 112 days, or 16 weeks, but Carmichael and Rice report that the average of 549 gestation periods of sows of various breeds at the Illinois Station was 114.6 days.[19] The shortest gestation period was 98 days and the longest 124 days. However, about three-fourths of the sows farrowed between the 113th and 117th days. Altho it is commonly believed that old sows carry their pigs 1 to 3 days longer than young sows, there was little evidence of this in these studies. There was also little correlation between the length of the gestation period and the weight of the pigs at birth, or between the sex of the pigs and the length of the period. On the average there were 8.1 pigs in the litters, weighing a total of about 20 lbs. In litters with few pigs, the weight at birth tended to be a trifle larger than in litters with more pigs than the average. There seemed to be a tendency for the larger litters to contain a slightly larger proportion of dead or immature pigs than in the smaller litters. Of a total of 5,657 pigs, 51.9 per ct. were males and 48.1 females.

Immature sows tended to produce fewer and smaller pigs than older animals. On the average, sows one to one and one-half years old had 7.5 pigs, while those two years old or older had 8.6. The average birth weight of the pigs from the younger sows was 2.44 lbs. and of those from the older sows, 2.61 lbs. Similarly, Iddings found at the Idaho Station[20] that gilts bred at 8 months averaged 7.7 pigs per litter; sows 24 months old averaged 9.6 pigs; and aged sows 10.6 pigs per litter. Carlyle[21] found that sows 4 years old or more bore 9 pigs to the litter on the average, the litter weighing 26 lbs., while 1-year-old sows averaged less

[19]Ill. Bul. 226. [20]Breeder's Gaz., 64, 1913, p. 241. [21]Wis. Bul. 104.

than 8 pigs, weighing but 15 lbs. From the records of 1,477 pure-bred sows of 8 breeds Rommel[22] reports that on an average there were 9 pigs to the litter, 50.1 per ct. males and 49.9 per ct. females.

Tho young sows have smaller litters than mature sows, they usually raise a larger percentage of their pigs, for they are less clumsy. In trials covering 4 years at the North Platte, Nebraska, Substation,[23] Snyder found that sows with their first litters farrowed 8.2 pigs on the average and raised 6.2 pigs. Old sows farrowed 11.1 pigs on the average, but raised only 6.5. Probably on the average there will be a greater difference than this in favor of old sows.

Since older sows generally raise more pigs than gilts with their first litters, it is a mistaken policy to rely chiefly on gilts for the breeding herd. Sows which produce especially good litters and which are good milkers and careful mothers should be retained as long as they are useful. Only the offspring from such proven mothers should be retained to replenish the breeding herd. By such selection much can be done to build up a herd which is much more profitable than the average. Unless there is some very good reason to expect better returns in the future, one should discard a sow raising a litter of less than 5 pigs, or one which is vicious with her pigs, in spite of being properly fed and cared for. A sow that can save and raise 8 pigs is a good producer and should be retained. The pigs in a litter of 8 usually will make larger, more uniform pigs, and in most cases are more profitable to the farmer than abnormally large litters, small in average size, and low in vitality.

1029. At farrowing time.—Even if the sows have been properly fed and cared for during the winter, heavy losses may occur among the young pigs at farrowing time, unless careful attention is given to the details which make success reasonably sure. Lack of care at this critical time results in heavy losses from sows lying on their pigs and from scours, thumps, and sore mouth. It has been estimated that in some seasons 40 per ct. of the pigs farrowed in the corn belt perish from these causes, all of which may be largely prevented by the right care and management.

At least 3 days before she is to farrow, and preferably even more, each sow should be removed from the herd and placed in a separate farrowing pen. This allows her to become accustomed to her surroundings and the presence of the herdsman, so she will be more quiet when farrowing. This pen should have been previously cleaned and disinfected, and should be dry, well-ventilated, free from drafts, and well lighted. If possible, it should be exposed for a part of each day to direct sunlight, so it will be warmer, and also because sunlight is the cheapest germicide. If the breeding dates have not been recorded, the sows should be watched closely as the farrowing season approaches, and each sow should be put in a farrowing pen as soon as the udder and teats begin to fill. After a sow starts to arrange her nest, she may be expected to farrow within

[22]U. S. D. A., Bur. Anim. Indus., Cir. 112. [23]Nebr. Bul. 147.

12 hours. Recording the breeding date is highly important where the litters come before the weather is warm, for otherwise sows will often farrow before they are expected, and their litters may perish from cold or lack of proper care. The sow should always be allowed to exercise each day after being put in the farrowing pen, as close confinement is injurious.

The farrowing place should be sufficiently warm so that a deep nest is not necessary to prevent the new-born pigs being chilled, for they may be crushed in a deep, bird-like nest. Cut straw or hay, chaff, and leaves are the best for bedding, provided they are reasonably free from dust. Long hay or straw may entangle the pigs.

Every farrowing pen should be supplied with fenders to protect the little pigs during and after farrowing. These consist of 2 by 8 inch planks fastened as shelves about eight inches from the floor, along both sides of the corner in which the sow makes her bed. This largely prevents the sow from squeezing the pigs against the wall or lying on them while they are small. If the farrowing pen has a concrete floor, a board overlay in the nest corner makes the sow's bed warmer, drier, and cleaner.

As soon as the sow is put in the farrowing pen, her ration must be reduced and also be made more laxative. A good general rule is to feed only half as much concentrates as previously, with wheat bran forming one-third of the ration by weight. Linseed meal is also a helpful addition at this time, and the feeding of legume hay should be continued. Some breeders prefer to feed the concentrates as a thin, warm slop. This may satisfy the sow better and aid in getting her to take plenty of water.

If brood sows are kept thrifty by feeding them well-balanced rations and forcing them to get plenty of exercise, and if constipation is prevented, little trouble will be experienced from sows failing to furnish enough milk for their pigs or from being restless and irritable, which may lead to their eating the young. If a sow has a feverish udder, which often is a result of constipation, a light application of kerosene and lard, well rubbed in, will relieve the pain.

At farrowing time the herdsman should be on hand to render assistance if necessary, but should otherwise not disturb the sow. In large herds it has been found an exceedingly profitable plan to have an experienced man near by during the night at this time to inspect the sows every three hours. The farmer with only a few sows will find that a few night trips to the hog house at farrowing time will save many a litter, and prove a most profitable investment of his time and energy.

In the case of heavy, clumsy sows, or those which are very restless at farrowing time, it is a good plan to separate the pigs from the dam by placing them in a warm box or half barrel as they are farrowed. Sows properly handled before farrowing will not usually resent such separation. When the sow has become quiet, and as quickly as possible after farrowing is over, they should be, one by one, carefully replaced at a

nipple and watched until their safety is assured. If the sow is very cross and irritable, it may be necessary to keep the pigs away from her for a few days, returning them to nurse every two or three hours. A chilled pig may be revived by immersing it up to the head in water as warm as the hand will bear.

At birth, pigs have long, sharp "wolf" teeth, which are also called "needle" teeth or "black" teeth. These are temporary tusks, and, so far as is known, are of no benefit to the pigs. On the other hand, they are apt to lacerate the udder of the sow and also to wound the other pigs as they tussle among themselves. Therefore the most experienced hogmen commonly break off these teeth close to the gums with nippers made for the purpose.

It is of course necessary to mark pure-bred pigs that are to be registered and the ear notching system has given as good or better results than any other method employed. Its main advantage is that pigs can be marked within a few hours after birth, avoiding danger of mistakes, while a small pig's ear is too small and tender to permit marking by buttons or labels until several weeks of age. Marking the pigs is also advisable even in grade herds, to permit selecting gilts for the breeding herd from the best litters and out of the best dams.

1030. Feed and care of sows and litters.—The sow should receive no feed for about 24 hours after farrowing, but as she will usually be somewhat feverish, she should be supplied all the lukewarm water she will drink. After the first day she should be given a small feed of bran and shorts or of such a mixture as bran, ground grain, and a little tankage—gradually increasing the amount as her milk flow grows larger, until after 10 to 14 days she will be on a full ration.

Sows suckling their litters have the same general nutrient requirements as dairy cows. (**147–150**) They need a liberal allowance of concentrates rich in protein and mineral matter, especially calcium and phosphorus. It is essential to feed them well, so that the young pigs may get a good start in life. Furthermore, at no time do pigs make as economical gains as when suckling their dams. Good mothers with large litters will usually lose flesh in spite of the most liberal feeding.

The rations for suckling sows may consist chiefly of the farm grains, but plenty of protein-rich feeds, such as skim milk or buttermilk, tankage, linseed meal, wheat middlings, etc., should be added to supply ample protein. Rations having nutritive ratios of 1:6.0 to 1:7.0, as recommended in Appendix Table V, will be found satisfactory. Five per ct. by weight of alfalfa or other legume hay may well be included in the concentrate mixtures for suckling sows, or they may be still allowed access to legume hay in a rack, if pasture is not yet available. For the best results there should be in the ration of all suckling sows not on pasture, either some feed of animal origin or else legume hay. The concentrates may be fed either dry or in the form of a slop. Just as early as is possible the sows and their litters should be turned on good pasture.

In the northern states the earliest pasture will usually be furnished by bluegrass or fall sown rye. (**982, 993**)

The following concentrate mixtures will be found suitable for sows suckling litters. These may be altered to suit local conditions, provided the ration is balanced.

(1) Corn, barley, or grain sorghum, 70 lbs.; standard middlings, 15 lbs.; tankage, 10 lbs.; chopped alfalfa, 5 lbs.

(2) Ground corn, barley, or grain sorghum, 50 lbs. and ground oats or middlings (standard or flour), 50 lbs., fed with 1.5 to 2.0 lbs. of skim milk or buttermilk for each pound of the mixture.

(3) Corn, barley, grain sorghum, etc. with 2 lbs. of skim milk or buttermilk to each pound of grain.

(4) Corn, barley, grain sorghums, etc., 50 lbs.; middlings, 35 lbs.; linseed meal, 10 lbs.; tankage, 5 lbs.

Such simple rations as grain and tankage, or for sows on pasture, grain and middlings or linseed meal, are quite satisfactory, but many breeders prefer mixtures containing more variety and including some bulky feed. Corn may be fed as ear corn or shelled corn (preferably soaked in the spring when it is hard and dry) or it may be ground and mixed with the other concentrates. The smaller cereals should always be ground for sows, if possible.

For sows and litters not on pasture, it is wise to supply a suitable mineral mixture, but there is no need of this being an expensive proprietary mixture. (**916**)

1031. The sow as a milk producer.—There is but little information concerning the milk yield of sows or regarding the composition of their milk, as it is difficult to milk sows and secure representative samples. In studies at the Wisconsin Station[24] Carlyle determined the milk yield of 12 sows of 3 breeds by keeping the pigs from their dams except for short periods at intervals of 2 hours by day and 4 by night, when they were allowed to suckle. They were weighed collectively before and after nursing, and the increase in weight was credited as milk drawn from the dam. With extreme difficulty samples were also drawn for chemical analysis. The average daily milk yield for Berkshire, Poland-China, and Texas "razor-back" sows ranged from 4.9 to 6.3 lbs. daily. The average total yield for 84 days, by which time they went dry, was 429 to 532 lbs. Some sows gave twice as much milk as others.

It is shown in Appendix Table I that sows milk is richer than cow's milk in all nutrients, and especially in fat, for it contains on the average 6.7 per ct. fat. Woll[25] found the fat globules of sow's milk only one-fourth as large as those of cow's milk, but 8 times as numerous.

1032. Feeding the litters.—When 2 to 3 weeks old, the pigs will begin to eat grain from their mother's trough. As the milk yield of a sow begins to decline after about 3 weeks, it is important that the pigs be now supplied additional feed, where the sows can not get at it. This

[24]Wis. Bul. 104. [25]Wis. Rpt. 1897.

is best done by providing a "creep" in a corner of the paddock or pasture, with openings of such size that the pigs can run in and out, while the sows are excluded. At first a little shelled corn seems about the most palatable feed. Later they may be fed a suitable mixture of concentrates, either being hand-fed all they will clean up twice or three times a day or else being fed by means of a self-feeder. For young pigs skim milk and buttermilk are easily the best of all protein-rich feeds. Nothing else aids so greatly in keeping them growing lustily. The concentrates fed pigs at this time should consist of the farm grains, with a considerable proportion of protein-rich feeds like middlings (standard middlings or preferably flour middlings), linseed meal, and tankage. If there is an abundance of skim milk or buttermilk, relatively little of other high-protein feeds need be used. Where no dairy by-products are available, such a mixture as the following is good for young pigs: Corn, barley, or grain sorghum, 50 lbs.; standard or flour middlings, 40 lbs.; tankage, 10 lbs. For very young pigs ground oats, with the hulls sifted or floated out, and red dog flour are excellent feeds, but they are often expensive.

Young pigs must always have plenty of exercise, especially when liberally fed, or some will be almost sure to die from thumps. On pasture the pigs will usually not suffer from lack of exercise, but special precautions are necessary with early spring litters in the northern states. When it is too cold outside, the litters may be turned together in the alley of the hog house, where they will get much exercise playing and tussling about. If the pigs show a tendency to become too fat the first few weeks, the dam's ration should be reduced gradually, so she will give a little less milk. Scours should be avoided by keeping the quarters dry and clean and the troughs sanitary. Overfeeding the sows or letting the pigs run out in a cold rain are other frequent causes of this trouble.

Boar pigs not to be kept for the breeding herd should be castrated when about 6 weeks old, or 2 weeks before weaning. This should be done on a clear, cool day, and the pigs should be kept in dry, clean quarters afterwards. Before the operation the pigs should receive only a light feed.

1033. Weaning time.—When only one litter of pigs is raised a year, the pigs may run with their dams 10 to 12 weeks, or the sow may be allowed to wean the pigs herself. However, when 2 litters are to be raised, the pigs must be weaned at the age of about 8 weeks. The sow should be separated from the pigs, and only returned 2 or 3 times, long enough for them to empty the udders. On weaning, pigs of the same size should be placed in groups of not over 20, in order that each may receive its share of feed and also have proper care and attention. It is especially important that the pigs have excellent pasture at this time.

Since the pigs no longer get their mother's milk, the ration after weaning should contain a somewhat larger proportion of protein-rich feeds than before. An abundance of skim milk or buttermilk with grain

should solve all difficulties. (957–60) In the absence of this, the proportion of tankage, linseed meal, wheat middlings, etc. should be large enough to provide a nutritive ratio of 1:4.0 or 1:4.5 for pigs not on pasture and of 1:5.0 or 1:6.0 for those having good forage.

1034. Growing and fattening pigs.—In the preceding chapter the various rations which are satisfactory for growing and fattening pigs have been discussed in detail. A study of the various trials there reported will show anyone which combinations of feed are most economical under his local conditions.

The importance of good protein-rich pasture for all swine thruout the entire growing season cannot be too strongly emphasized. Pasture is especially important for young pigs, as it keeps them growing thriftily, and also greatly reduces the cost of the gains made. In fact, no one should expect a good profit from his pigs if he fails to provide this nutritious and economical feed. In addition to such pasture as alfalfa, clover, or rape, at least 2 lbs. of concentrates daily per 100 lbs. live weight should be fed, except where pasture is unusually cheap compared with grain, and the allowance of concentrates should never be less than 1 lb. daily per 100 lbs. live weight. (924) Pigs should gain at least one-half to three-fourths pound a day.

In the corn belt, self-feeding pigs on pasture has become a common practice, except for breeding stock. The use of the self-feeder for growing and fattening pigs has been discussed fully in a preceding chapter. (924–7) Where the amount of concentrates fed in summer on pasture is limited, the pigs should be finished in the fall on all the concentrates they will eat, hand-fed or self-fed. In the corn belt when new corn is ready, pigs are quite commonly fattened on new ear corn or snapped corn, along with a suitable protein-rich supplement. As has been pointed out previously, turning pigs into standing corn to "hog down" the crop is often an economical practice. (942)

Whether to crowd spring pigs to an early finish by self-feeding them concentrates on pasture, or whether to force them to consume more pasture by restricting their concentrate allowance, will depend entirely on the relative prices of grain and pasture, and the prices for pork at the various times in the fall and winter. (983) Many corn belt farmers find it most profitable to have the spring pigs farrowed early and then to crowd them on self-feeders for an early market, so that they can sell them in the fall before the usual slump in the price of pork occurs. In the West, where alfalfa pasture or other pasture is cheap, compared with grain, it is usually more profitable to restrict the allowance of grain and finish the pigs for a later market, perhaps after prices have recovered somewhat from the usual fall slump. Pigs should always be provided with an abundance of fresh water in a trough or an automatic waterer. If self-feeders and automatic waterers are used, it should be borne in mind that even with these labor-saving devices one cannot expect success if he does not give the proper attention to his pigs. One should see daily

that the feeders and waterers are working properly and should clean them out when necessary—in short, he should be sure that all is going well with the animals.

As has been pointed out before, salt should always be supplied to swine, including growing and fattening pigs. (**916**) If the pigs are on first-class protein-rich pasture, there is probably little or no advantage in feeding a mineral supplement in addition to the type of well-balanced rations recommended in the preceding chapter. However, for pigs not on good pasture, feeding a simple mineral mixture, such as has been recommended before, is undoubtedly advantageous. Also it is possible that better bone will be produced in breeding stock if a mineral supplement is added to the ration. (**916**)

1035. Raising breeding stock.—Pigs selected for the breeding herd, both sows and boars, should be fed so they will develop good size and strong bone, but should not be allowed to become nearly so fat as pigs that are being finished for market. If the spring pigs are being fed a limited allowance of concentrates on good pasture and are receiving a well-balanced ration, it may not be necessary to separate the gilts to be retained for breeding from the other pigs until full feeding is started in the fall. On the other hand, if the pigs intended for the market are being fattened as they grow by self-feeding or by hand-feeding a full fattening ration, the breeding stock should be separated soon after weaning, so they may be fed a ration suited to their needs. This should include a larger proportion of protein-rich feeds than for the fattening pigs, and they should be fed just enough concentrates in addition to good pasture to keep them growing vigorously. For young sows and boars most breeders prefer concentrate mixtures containing a reasonable proportion of rather bulky feeds, such as ground oats, wheat bran, or standard middlings. If possible, some protein-rich feed of animal origin should be included in the ration, such as dairy by-products, tankage, or fish meal. This is especially important if the pigs are not on first-class pasture.

Tho simple mixtures may be entirely satisfactory, such a mixture as the following may be considered ideal for such stock: Corn, barley, or grain sorghum, 40 lbs.; ground oats, 30 lbs.; standard middlings, 20 lbs.; linseed meal, 5 lbs.; tankage, 5 lbs. If plenty of skim milk or buttermilk is available, a mixture of half corn, barley, or grain sorghum and half oats or standard middlings should be entirely satisfactory.

Sows and boars of the larger breeds should reach a weight of 300 lbs. or over at one year of age, if properly fed and managed.

1036. Age to breed gilts.—Commonly spring gilts not intended for showing are bred in the fall and farrow when they are about a year old. Those intended for a show herd are usually not bred until they are a year old, in order that they may mature earlier and reach a larger size. Thus under general farm conditions gilts are commonly bred when less mature than any other class of farm animals. There is a widespread opinion

among breeders that breeding immature females retards the growth of the young mother and diminishes her ultimate size, and also that it results in offspring which are smaller and less thrifty. To study this matter Mumford and colleagues have conducted extensive investigations covering over 12 years at the Missouri Station,[26] in which some sows and their offspring in the following generations have been bred as early as they came in heat. Other sows and their offspring have been bred for the first time at 18 months of age, and still others not until they were 30 months of age. All were fed liberally on well-balanced rations.

It was found that immature sows bred at 5 months of age and twice a year thereafter may be expected to develop into somewhat smaller animals at maturity than if they had not been bred until later. This results not from any checking of the growth during gestation, for pregnancy tended to increase the rate of growth in young sows. The smaller size was due to the lactation period being a heavy drain on the dam, which checked the growth of the immature sow while nursing her young. Mumford concludes: "The diminished size of mature sows bred at an early age has no very important practical significance in the production of swine for market, since the difference in size at maturity between animals bred at a very young age and those bred at a later age, is not significant."

With reference to the effect of early breeding on the offspring of young mothers he states,[27] "The only apparent effect upon the offspring of very young mothers is the effect which would be anticipated as the result of the failure on the part of the young mother to supply a sufficient amount of milk for the most rapid growth of the offspring. This effect is not commercially significant, and as an average of many years of experiment it seems probable that it requires about ten days longer for the offspring of very young sows to reach a weight of 250 lbs., than for the offspring of mature animals to reach the same weight."

Had early breeding been combined with scant feeding, the result on both the dams and the offspring would have unquestionably been marked.

1037. Number of litters a year; fall pigs.—Whether his sows should have one or two litters a year is a problem of great importance that every swine raiser must decide. The answer should depend on the local conditions, especially on the winter climate, the shelter which can be furnished, and the feeds available. In mild climates the sows should raise two litters as a rule, for this will reduce the cost of pork production materially. (**1041**) The fall litters in such sections should prove as satisfactory as the spring pigs, for they can be furnished pasture until late in the year and, in the southern states, even during the winter. Often even better profits can be made from fall pigs under favorable conditions than from the spring litters, for they reach market in the spring or summer when the prices are usually materially higher than in autumn.

[26]Mo. Res. Bul. 45. [27]Information to the authors.

Where the winters are long and severe, it is not best to attempt to raise fall pigs unless the sows and pigs can be given good care. Under proper conditions, especially where dairy by-products are available, two litters a year can be raised with great success even in the extreme northern states. The first essential is to have the fall pigs farrowed early —not later than the middle of September. They can then get a good start on pasture before cold weather sets in. Obviously, to secure early fall litters, the spring pigs must be farrowed by March or early in April. Commonly sows will not come in heat until after their litters are weaned, and this makes breeding for early fall litters impossible with sows which have farrowed late in the spring. Trials by Robison at the Ohio Station[28] show that if the pigs are separated from the sows over night for 4 or 5 successive times the sows will generally come in heat so they may be bred. This practice does not seem to injure the pigs or the sows in the least.

Suitable quarters must always be provided for fall pigs where they will be dry and comfortable during the cold, wet weather, and where they may be fed after the weather becomes chilly.

In trials by Morrison and Bohstedt at the Wisconsin Station[29] in which various rations for fall pigs have been compared, the pigs have remained more thrifty after the pasture was gone and have made considerably better gains when a small amount of legume hay was included in the ration, especially if no dairy by-products were fed. This furnishes good-quality protein, increases the amount of calcium, and supplies the fat-soluble vitamine. Young pigs can not use much dry roughage, even choice legume hay. Therefore, if much hay were fed, unsatisfactory results would be secured. In these trials, including only 4 to 5 per ct. by weight of chopped alfalfa in the ration has given excellent results. If the hay is of choice quality, the pigs may eat enough if it is merely fed uncut in a rack. Otherwise the hay should be chopped and mixed with the concentrates. As is mentioned elsewhere, legume chaff may be used where there are no facilities for chopping the hay. (**1016**) With pigs weighing up to 100 lbs. which have had no dairy by-products, excellent results have been secured with a mixture of ground corn, 80 lbs.; linseed meal, 5 lbs.; tankage, 10 lbs.; and chopped alfalfa, 5 lbs. For heavier pigs only enough linseed meal and tankage should be included to balance the ration. (Appendix Table V.) If shelled corn or ear corn is fed, then the pigs may be self-fed separately such a mixture as tankage, 2 parts; linseed meal or corn germ meal, 1 part; and chopped alfalfa or clover hay, 1 part. If plenty of skim milk or buttermilk is available, the ration may consist of only grain or grain by-products along with a little legume hay. When the grain fed with the dairy by-products is yellow corn, there is less need of supplying the legume hay, as the yellow corn is rich in fat-soluble vitamine. (**939**) However, even with yel-

[28] Ohio Mo. Bul. 29.

[29] Unpublished data.

low corn young fall pigs in the northern states may be more thrifty with a little choice legume hay in the ration.

1038. Orphan pigs.—If a sow becomes seriously sick or dies shortly after farrowing a litter, the problem arises as to how the pigs may be reared. The best plan is to get sows which have rather small litters of the same age to adopt the orphans. This may usually be accomplished by putting the orphans with the foster mothers for a few times when their own pigs are nursing. After this, they will usually own the orphans. Where no such sows are available, the pigs may often be raised by hand, if the herdsman has enough patience. The best results are secured if the pigs are fed sweet whole cow's milk 6 to 8 times daily until they are 3 or 4 weeks old. However, Evvard of the Iowa Station[30] found that good results could be secured on 3 feeds a day from the start. In his trials the pigs did better on whole milk alone than when cream or sugar was added to make the composition of the milk more like that of sow's milk. (**1031**) A quart of milk per head daily is enough, if they are supplied plenty of suitable concentrates in addition as soon as they can be taught to eat solid food. The first few days the milk should be warmed to 100° F. before feeding. Until the pigs can be taught to drink from a trough, a nursing bottle may be used to feed the orphans. Care should be taken to supply fresh water at all times.

1039. Sanitation and disease prevention.—Altho the losses from hog cholera and other infectious swine diseases have been greatly reduced in recent years by scientific methods of prevention and treatment, still the annual death rate is much higher for swine than for horses, cattle, or sheep. This is due to the fact that many farmers do not understand that sanitation is as important in pork production as proper feeding. If swine are kept in sanitary quarters and have an abundance of good, fresh pasture during the growing season, many of the ills they are subject to may be largely prevented. Not only will infection from worms and filth-borne diseases be greatly lessened, but pigs properly fed and cared for are better able to resist most diseases than those low in vitality.

Pigs which are infested with worms or lice can not be expected to make profitable gains. Lice may be readily eradicated by using crude petroleum or one of the standard stock dips. Worms not only produce serious results but are also most difficult to control.

Recent investigations of the United States Department of Agriculture show that the common intestinal round worm (*Ascaris lumbricoides*) is one of the chief causes of death or lack of thrift among young pigs. In addition to the damage it does as an intestinal parasite, it has been proven that in its early stage of development, while still too small to be seen by the naked eye, it travels in the blood stream from the intestines to the lungs. Later it returns to the intestines by way of the windpipe and gullet and there grows to maturity. If many of the young worms

[30]Information to the authors.

invade the lungs at the same time, the results are likely to be serious. The pigs often shows the symptoms known as thumps and may die of pneumonia. Those that survive frequently are stunted.

Pigs become infected by swallowing the eggs of the parasite, which are of microscopic size and are found in the manure of infected hogs or in the soil of lots contaminated by the droppings from infected hogs. It has been estimated that one full-grown female worm in the intestine of a hog may produce as many as 80,000,000 eggs. The eggs as they are passed out of the body of the hog in the droppings are not at first infectious, but in a few weeks or months, depending upon the weather and various other conditions, the egg reaches a stage of development at which it contains a tiny worm within its shell, and it is then infectious, if swallowed. The eggs are long-lived and very resistant to cold weather and drought. Also they are not killed by most chemical disinfectants. Commonly the parasites may be found in one out of three hogs of breeding age.

As pigs are most susceptible to infection and suffer most seriously from the worms during the first few weeks of life, the United States Department of Agriculture has worked out what is known as the "McLean County System" of prevention, because first tried on a large scale in that county of Illinois. According to Ransom, in this system the farrowing pens are cleaned thoroly prior to the farrowing season and then scrubbed with boiling water and lye. Before a sow is placed in a farrowing pen she is cleaned carefully of mud and dirt and her udder is washed with soap and water, to get rid of as many worm eggs as possible. After farrowing the sows and pigs are not allowed to go out of the farrowing pen until they are taken by wagon to a clean pasture, on which there have been no pigs that season. No other hogs should have access to this pasture, and the young pigs must not be allowed to run back to the hog lots or barn. The pigs are kept in this pasture until they have reached a weight of 100 lbs., after which they are not likely to suffer from worm infestation, even if exposed.

Pigs infested with worms should be treated with a reliable worm remedy. Combinations including santonin have been widely used with good results, but this drug is now high in price, and oil of chenopodium (American wormseed) is being commonly substituted for it. Before administering a worm remedy, feed should be withheld from the pigs for 24 hours.

In sections of the country where hog cholera is common the only safe plan is to immunize all animals by the double method of vaccination. Where this dreaded disease is rare, one must be on guard at all times, and protect his swine by vaccination if there is an outbreak of cholera in the vicinity. Breeders of pure-bred swine usually keep their herds always immunized by the double method of vaccination.

1040. Shipment to market.—Where a farmer ships his fat hogs direct to a central market he naturally wishes to reduce the shrinkage in weight

to a minimum or his profits will be reduced materially. The following advice of Smith[31] will be of service at this time:

There should be no very radical change in the ration of the hogs two or three days before loading, but if they have been fed largely on slop, they should be changed gradually to dry feed, preferably corn for the most part. Hogs which have been on pasture will shrink less if confined to a dry lot for a week before shipping. The regular feed should be omitted just before hauling to the shipping point and the advisability of feeding before loading or while in transit should be determined by the distance to market. If the hogs will arrive at the market within 24 hours of shipment, it is doubtful whether much feed should be given the day of loading.

The cars should be thoroly cleaned before loading. In winter clean straw should be used for bedding and in summer, sand, if available. Overloading in hot weather is fatal. The hogs will ride best if the car is just comfortably full when the hogs are lying down. In driving and loading, the hogs should not be hurried or excited, and they must not be beaten. Crippled hogs sell at a discount of $1.00 per cwt. and bruises also affect the selling price, as they spoil the appearance of the carcass. In hot weather the hogs should be sprayed with a hose before loading and also when possible at stopping points in transit. Suspending from the roof of the car two or three sacks containing large cakes of ice helps prevent overheating, if it is very hot. In extreme winter weather it is a good plan to protect the hogs from cold winds by nailing a few strips of building paper on the inside of the car.

1041. Cost of pork production.—In spite of the importance of having accurate data on the average cost of producing pork under farm conditions, but little information has yet been published on the matter. The approximate feed cost of growing and fattening pigs under good conditions may be readily estimated from the data secured in the numerous trials summarized in the preceding chapter. To this must be added the cost of the pigs at weaning time, and the other costs, in addition to feed, of carrying them from weaning time to market weights. These costs include labor, interest, depreciation, and insurance on buildings and equipment; interest on money invested in the pigs; mortality risk; veterinary expenses, such as vaccination against hog cholera; and any other miscellaneous charges.

For simplicity the total cost of producing each 100 lbs. of pork is often estimated in terms of the price of a bushel of corn, all other costs being reduced to this equivalent. From a study of the available data, Smith[32] gives the following as the representative cost of producing a 225-lb. finished pig in the corn belt under various systems of management. The last column of the table shows the estimated total cost of producing 100 lbs. of live pig, expressed in terms of the price of a bushel of corn:

[31]Pork Production, pp. 362–6.

[32]Pork Production, pp. 350–61.

Cost of producing pork in terms of corn

System of management	Cost of producing 225-lb. pig in terms of bushels of corn				Cost of producing 100 lbs. pork, live wt., in bushels of corn
	Feed cost	Labor cost	Other costs	Total cost	
	Bu.	Bu.	Bu.	Bu.	Bu.
A. Pigs from gilts, 5 pigs raised per litter	18.24	2.03	5.64	25.91	11.51
B. Pigs from mature sows, 1 litter of 7 pigs a year	18.05	1.62	5.62	25.29	11.24
C. Pigs from mature sows, 3 litters of 7 pigs each every 2 yrs. after maturity	17.73	1.47	5.38	24.58	10.93
D. Pigs from mature sows, 2 litters of 7 pigs a year after maturity	17.56	1.37	5.23	24.16	10.74

Under *A* is estimated the cost of pork production with spring pigs from gilts which raise 5 pigs on the average and are fattened and sold for pork as soon as their pigs are weaned. According to these estimates, the approximate total cost of raising a 225-lb. pig under this system is equal to the price of 25.91 bushels of corn. The cost of producing pork, per 100 lbs. live weight of pigs, is equal to the price of 11.51 bushels of corn. With corn at 56 cents a bushel on the farm, the total approximate cost of producing a 225-lb. pig would be $14.51 and the cost of production per 100 lbs. of live pigs would be $6.45.

According to these estimates, if mature sows raise on the average 7 pigs to the litter, the costs are lower than with gilts raising 5 pigs per litter. The estimates are based on the old sows being retained until they are 4 years old, when they are fattened and sold. Compared with the figures for the gilts, if mature sows raise 2 litters of 7 pigs each a year, the cost of production, per 100 lbs. of live pigs, would be only as much as the price of 10.74 bushels of corn.

These data will be helpful in estimating the costs of pork production at local prices. However, the figures can be taken only as approximations of what is possible under good systems of feeding and management and where larger litters are raised than is often the case. Furthermore, any system of estimating costs of farm products in terms of feed or other single commodities gives results which are only rough approximations when applied to different years. This is due to the fact that the price of feed may rise or fall more proportionally than the other costs.

These estimated costs of producing pork correspond quite closely with the actual ratio between the average price of hogs and corn on the Chicago market. Wallace's Farmer[33] reports that the average price of hogs per 100 lbs. live weight at Chicago was equal to 11.3 times the price of No. 2 cash corn per bushel for the 10-year period 1908 to 1917. For earlier periods the values were as follows: 1858 to 1867, 10.6 bushels;

[33]Wallace's Farmer, 42, 1917, p. 1726.

1868 to 1877, 11.7 bushels; 1878 to 1897, 11.0 bushels; 1888 to 1897, 11.8 bushels; and 1898 to 1907, 12.2 bushels.

One of the most important factors influencing the cost of producing pork is the number of pigs raised per litter. For example, let us suppose that the net cost of raising gilts up to the time their litters are weaned is $25.00 a head, after crediting what they are worth for pork at that time. The cost per pig at weaning time will then be only $3.57 if 7 pigs are raised per litter, but it will be $6.25 if only 4 pigs are raised per litter. This shows the importance of building up by careful selection a herd of sows which will not only farrow large litters of pigs, but which are also kind mothers and good milk producers. When one has such sows and then feeds and cares for them and their offspring as a true stockman should, then and only then can the cost of pork production be reduced to the minimum.

APPENDIX

Table I. Average Percentage Composition of American Feeding Stuffs

This table is an exhaustive compilation, made by F. B. Morrison, of the analyses of feeding stuffs reported by the State Experiment Stations and the United States Department of Agriculture. The preparation of this table and Appendix Tables II and III required the time of trained assistants equivalent to one person working steadily for three years, in addition to the supervision of the author. The completeness of the data is evident from the fact that over 53,000 analyses have been gathered into this table. The value of the averages here given is shown by the large number of complete analyses combined for the leading feeding stuffs. For example, 2,556 complete analyses enter into the average for choice cottonseed meal, 4,641 for standard wheat middlings, 7,742 for wheat bran, etc.

When possible, separate averages are given for forage crops at different stages of maturity and with different contents of water, for high- and low-grade feeds of the same name, etc. For reasons given in the text, averages for the various proprietary mixed feeds are not here given. (**288**) The figures for a few feeds, for which American analyses are not available, have been taken from foreign sources. Where the scientific names of plants are given in the text, they are not repeated in this table, for they may be readily found by referring to the index. In other instances the scientific names of the plants are here given.

This and the following tables are fully protected by copyright.

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
Concentrates	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grains and seeds							
Barley, common	9.3	2.7	11.5	4.6	69.8	2.1	298
Barley, hulless	9.3	2.8	10.8	2.9	71.6	2.6	2
Bean, Adzuki, *Phaseolus angularis*	14.0	3.6	21.0	4.0	56.7	0.7	2
Bean, navy	13.4	3.6	22.7	5.8	53.0	1.5	4
Broom-corn seed	11.8	2.9	10.2	8.2	63.5	3.4	4
Buckwheat	12.1	2.1	10.8	10.3	62.2	2.5	18
Carob bean and pod	13.3	2.6	6.8	9.3	65.8	2.2	8
Chess, or cheat, seed	7.7	4.1	10.5	7.2	68.6	1.9	1
Corn, dent, well dried	10.5	1.5	10.1	2.0	70.9	5.0	440
Corn, dent, grade No. 1	12.0	1.5	9.9	2.0	69.7	4.9	....
Corn, dent, grade No. 2	14.8	1.4	9.6	1.9	67.6	4.8	....
Corn, dent, grade No. 3	16.5	1.4	9.4	1.9	66.1	4.7	....
Corn, dent, grade No. 4	18.5	1.4	9.2	1.8	64.6	4.6	....
Corn, dent, grade No. 5	20.5	1.3	9.0	1.8	63.0	4.4	....
Corn, flint	12.2	1.5	10.4	1.5	69.4	5.0	52
Corn, pop	9.4	1.6	12.1	2.0	69.7	5.2	7
Corn, soft (immature)	30.6	1.0	7.4	1.2	56.0	3.8	154
Corn, sweet, mature	9.3	1.8	11.5	2.3	67.2	7.9	67
Corn-and-cob meal	10.4	1.5	8.5	7.9	67.6	4.1	....
Corn and oat feed	11.4	2.8	9.6	7.4	65.0	3.8	1,789
Corn and oat feed, low grade	9.5	4.6	8.9	13.7	59.7	3.6	386
Cotton seed	9.4	4.6	19.5	22.6	24.9	19.0	38
Cowpea seed	11.6	3.4	23.6	4.1	55.8	1.5	30
Darso grain	11.7	1.8	11.4	3.6	68.0	3.5	2
Durra grain	9.9	2.0	10.1	1.7	72.8	3.5	5

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—cont. *Grains and seeds*—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Emmer (spelt)	8.7	3.7	11.9	10.1	63.7	1.9	37
Emmer, without hulls	10.5	1.5	14.9	2.1	68.5	2.5	4
Feterita grain	11.1	1.5	12.5	1.7	70.1	3.1	4
Feterita-head chops	11.2	2.7	11.1	6.6	66.0	2.4	3
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Frijole, *Phaseolus vulgaris*	9.6	4.4	24.6	4.2	56.1	1.1	1
Horse bean	12.6	3.8	26.2	7.1	49.4	0.9	2
Jack bean, *Canavalia ensiformis*	11.5	3.0	23.8	8.7	50.4	2.6	1
Kafir grain	11.8	1.7	11.1	2.3	70.1	3.0	135
Kafir-head chops	12.5	2.8	9.7	6.4	65.9	2.7	21
Kaoliang grain	9.9	1.9	10.5	1.5	71.9	4.3	12
Lamb's quarter seed, *Chenopodium album*	9.8	3.0	14.1	19.1	46.2	7.8	1
Mesquite bean and pod	6.1	4.5	13.0	26.6	46.7	3.1	5
Millet seed, barnyard	10.2	5.6	10.7	16.0	52.8	4.7	3
Millet seed, foxtail	10.8	3.6	12.1	8.4	61.0	4.1	28
Millet seed, hog, or broom-corn	9.1	3.3	11.8	7.8	64.7	3.3	52
Millet seed, pearl	8.0	2.3	11.7	2.3	69.0	6.7	1
Milo grain	10.7	2.8	10.7	2.4	70.5	2.9	125
Milo-head chops	10.3	3.1	10.0	5.9	68.1	2.6	40
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490
Oats, light weight	8.7	4.5	12.3	15.4	54.4	4.7	22
Oats, ground, low grade	10.2	4.0	9.6	18.5	53.8	3.9	8
Peanut, with shell	5.9	2.7	25.2	17.5	12.5	36.2	64
Pea, field	9.2	3.4	22.9	5.6	57.8	1.1	6
Pea, garden	11.8	3.0	25.6	4.4	53.6	1.6	8
Pigeon-grass seed	10.7	6.6	14.4	17.2	45.7	5.4	3
Pigweed seed	6.3	4.2	15.0	15.2	52.5	6.8	1
Rice, rough	9.6	4.9	7.6	9.3	66.7	1.9	10
Rye	9.4	2.0	11.8	1.8	73.2	1.8	108
Sesbania macrocarpa	9.2	3.3	31.7	13.5	38.0	4.3	1
Shallu grain	9.7	1.6	12.5	1.7	71.1	3.4	3
Sorghum grain	12.7	1.9	9.2	2.0	70.8	3.4	13
Soybean seed	9.9	5.3	36.5	4.3	26.5	17.5	121
Sunflower heads	7.3	6.7	12.6	24.4	34.6	14.4	1
Sunflower seed, with hulls	6.9	3.1	16.1	27.9	21.3	24.7	9
Sunflower seed, without hulls	4.5	3.8	27.7	6.3	16.3	41.4	6
Tepary, *Phaseolus acutifolius*, var. *latifolius*	9.5	4.2	22.2	3.4	59.3	1.4	1
Velvet bean, seed	11.7	2.6	20.8	7.5	51.0	6.4	2
Velvet bean, seed and pod (velvet bean feed)	9.7	4.2	18.4	12.7	50.6	4.4	37
Wheat, all analyses	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat, Atlantic states	11.2	1.8	11.7	2.0	71.3	2.0	223
Wheat, Minn., N. D., S. D., Nebr., Kan.	10.4	1.8	13.5	2.4	69.8	2.1	190
Wheat, Miss. Valley, except above states	10.5	1.8	12.3	2.2	71.2	2.0	195
Wheat, Rocky Mountain states	8.5	2.0	13.3	2.1	71.9	2.2	193
Wheat, Pacific states	10.9	1.9	9.9	2.7	72.6	2.0	57
Wheat, spring	10.1	2.0	12.5	2.7	70.5	2.2	109
Wheat, durum	10.4	1.8	14.1	2.6	68.6	2.5	15
Wheat, Polish	9.5	2.3	20.3	2.0	64.2	1.7	4
Wheat, winter	10.9	1.8	11.7	2.0	71.6	2.0	94

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—cont. *By-products of grains and seeds; miscellaneous concentrates*	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Acorn, kernel and shell	27.9	1.1	3.4	17.8	45.4	4.4	1
Acorn, kernel	34.4	1.4	4.2	....	54.6	5.4	1
Bakery refuse	8.3	5.2	11.2	0.5	65.1	9.7	4
Barley feed, low grade	7.8	5.4	11.4	16.1	56.0	3.3	10
Barley bran, nearly all hulls	8.1	6.4	5.9	26.4	51.8	1.3	2
Barley screenings	11.4	4.2	11.5	9.5	60.6	2.8	4
Barley shorts, or barley feed, high grade	10.2	4.2	12.8	8.6	60.6	3.6	20
Beet pulp, dried	8.2	3.5	8.9	18.9	59.6	0.9	48
Beet pulp, molasses	7.6	5.6	9.5	15.9	60.7	0.7	21
Beet pulp, wet	90.7	0.4	0.9	2.1	5.7	0.2	10
Bread	33.8	1.5	7.9	0.7	55.4	0.7	2
Brewers' grains, dried	7.5	3.5	26.5	14.6	41.0	6.9	431
Brewers' grains, dried (below 25% protein)	8.2	3.8	23.1	15.0	43.5	6.4	139
Brewers' grains, wet	75.9	1.0	5.7	3.6	12.1	1.7	47
Buckwheat feed, good grade	11.8	4.4	19.3	17.9	41.4	5.2	18
Buckwheat feed, low grade	11.9	3.2	13.3	28.5	39.7	3.4	29
Buckwheat flour	12.8	1.1	7.9	0.6	76.1	1.5	11
Buckwheat hulls	10.3	2.1	4.4	43.7	38.5	1.0	15
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4	54
Cassava, dried	5.6	2.0	2.8	5.0	84.1	0.5	6
Cassava starch refuse	12.0	1.6	0.8	6.1	78.8	0.7	1
Cocoa shells	4.9	10.3	15.4	16.5	49.9	3.0	21
Cocoanut meal or cake, new process	10.0	6.0	22.1	11.0	47.9	3.0	....
Cocoanut meal or cake, old process	10.2	5.6	20.7	10.3	44.8	8.4	30
Cocoanut meal or cake, old process, high in fat	7.7	5.7	20.4	8.0	41.1	17.1	6
Corn bran	10.0	2.4	9.7	9.8	62.4	5.7	77
Corn cob	10.0	1.5	2.0	31.8	54.3	0.4	46
Corn germ meal	8.9	2.7	22.6	9.0	46.0	10.8	36
Corn gluten feed	8.7	2.1	25.4	7.1	52.9	3.8	800
Corn gluten meal	9.4	1.3	44.4	3.1	38.9	2.9	....
Corn, oat, and barley feed	9.7	3.5	11.4	9.2	61.7	4.5	60
Cottonseed cake, cold-pressed	7.9	4.2	26.1	24.0	30.1	7.7	64
Cottonseed kernel, without hull	6.7	5.3	32.8	3.1	17.5	34.6	8
Cottonseed meal, choice	7.5	6.2	44.1	8.1	25.0	9.1	2,556
Cottonseed meal, prime	7.8	6.6	39.8	10.1	27.4	8.3	1,322
Cottonseed meal, good	7.9	6.4	37.6	11.5	28.4	8.2	482
Cottonseed feed	8.3	4.9	24.5	21.4	34.6	6.3	406
Cottonseed-hull bran	8.4	2.5	3.4	34.8	49.7	1.2	9
Cottonseed hulls	9.7	2.7	4.6	43.8	37.3	1.9	66
Distillers' grains, dried, chiefly from corn	6.6	2.6	30.7	11.6	36.3	12.2	114
Distillers' grains, dried, chiefly from rye	7.2	3.9	23.1	10.9	47.1	7.8	7
Distillery slop, whole	93.8	0.3	1.9	0.5	2.9	0.6	9
Distillery slop, strained	95.9	0.3	1.4	0.2	1.5	0.7	8
Distillers' grains, wet	77.4	0.6	4.5	2.8	13.1	1.6	3
Flax feed	9.4	7.3	16.6	11.2	41.3	14.2	9
Flax screenings	8.6	8.2	15.4	15.5	40.5	11.8	13
Hominy feed	10.1	2.6	10.6	4.4	64.3	8.0	778
Hominy, pearled	10.6	1.2	7.8	1.0	76.1	3.3	5
Linseed meal, new process	9.6	5.6	36.9	8.7	36.3	2.9	182
Linseed meal, old process	9.1	5.4	33.9	8.4	35.7	7.5	714
Malt	5.8	2.9	18.0	9.0	60.6	3.7	2

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—cont. *By-products of grains and seeds; miscellaneous concentrates*—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Malt sprouts	7.6	6.1	26.4	12.6	45.6	1.5	253
Molasses, beet	22.0	7.0	9.0	....	62.0	....	....
Molasses, cane, or blackstrap	25.7	6.1	3.2	....	65.0	....	21
Molasses feeds, below 10% fiber	11.6	6.7	13.4	9.8	53.5	5.0	171
Molasses feeds, 10-15% fiber	11.7	7.2	12.2	11.8	52.9	4.2	22
Molasses feeds, over 15% fiber	9.3	9.8	13.7	18.6	45.8	2.8	11
Molasses-alfalfa feeds	13.5	9.2	12.0	17.2	46.7	1.4	5
Molassine meal	16.6	7.8	8.8	6.4	59.6	0.8	3
Mustard feed or bran	5.7	6.2	31.7	10.7	34.1	11.6	3
Oat dust	6.6	7.0	12.6	18.7	49.9	5.2	5
Oat feed, low grade (chiefly hulls)	6.5	6.2	5.5	27.4	52.4	2.0	16
Oat hulls	6.8	6.0	4.0	29.2	52.3	1.7	16
Oat kernel	6.9	2.2	14.3	1.4	67.1	8.1	179
Oat meal (rolled oats)	7.9	2.0	16.0	1.5	66.1	6.5	10
Oat middlings	6.9	3.2	16.3	4.3	62.5	6.8	28
Oat shorts	6.1	4.1	16.1	9.3	58.5	5.9	3
Palmnut cake	10.4	4.3	16.8	24.0	35.0	9.5	600
Pea bran	9.9	5.9	12.2	35.3	35.6	1.1	3
Pea hulls	7.2	3.6	6.9	43.6	37.5	1.2	3
Pea meal	10.9	3.6	23.8	4.6	55.7	1.4	8
Peanut kernel, without shells	5.3	2.3	30.5	2.5	11.7	47.7	104
Peanut oil feed, from unshelled nuts	7.5	4.5	34.1	23.1	22.2	8.6	100
Peanut oil meal or cake, from shelled nuts	6.6	4.8	44.8	7.6	26.0	10.2	37
Peanut shells, commercial	9.1	5.5	7.3	56.6	18.9	2.6	26
Potato flakes, dried	12.1	4.0	7.1	2.9	73.6	0.3	....
Potato flour	10.6	2.4	2.7	2.2	81.3	0.8	2
Rape seed cake	10.0	7.9	31.2	11.3	30.0	9.6	500
Red dog flour	11.1	2.5	16.8	2.2	63.3	4.1	259
Rice, polished	12.3	0.5	7.4	0.4	79.0	0.4	37
Rice bran, high grade	10.1	9.7	12.1	12.4	44.3	11.4	831
Rice bran, low grade	9.5	11.3	10.9	15.8	42.7	9.8	475
Rice hulls	9.3	16.9	3.3	35.4	34.0	1.1	15
Rice meal	9.5	9.1	11.8	9.3	48.7	11.6	42
Rice polish	10.0	4.8	11.9	1.9	62.3	9.1	1,013
Rye bran	11.4	3.5	15.3	4.0	62.7	3.1	26
Rye feed (middlings and bran)	11.5	3.8	15.3	4.7	61.5	3.2	186
Rye flour	11.8	0.8	7.9	0.4	78.0	1.1	6
Rye middlings	11.4	3.7	15.7	4.6	61.2	3.4	128
Sesame oil cake	9.8	10.7	37.5	6.3	21.7	14.0	150
Soybean oil meal	10.5	4.9	43.2	5.3	29.5	6.6	10
Starch feed, dry	9.3	1.8	15.4	7.2	59.4	6.9	13
Sunflower seed cake	10.0	4.2	34.8	10.9	21.8	18.3	1
Vegetable ivory nut meal	10.0	1.2	4.4	7.2	76.2	1.0	1
Wheat bran, all analyses	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Wheat bran, spring	10.4	6.3	15.7	10.2	52.6	4.8	218
Wheat bran, winter	10.6	6.3	15.7	8.8	54.2	4.4	138
Wheat bran, low grade	10.0	6.2	11.9	16.6	51.7	3.6	53
Wheat feed (middlings and bran)	10.1	5.2	16.8	7.6	55.7	4.6	1,601
Wheat flour, graham	12.0	1.5	13.7	1.9	68.8	2.1	11
Wheat flour, patent	12.3	0.5	10.9	0.4	74.6	1.3	73
Wheat middlings, flour	10.7	3.7	17.8	4.7	58.1	5.0	470
Wheat middlings, standard (shorts)	10.5	4.4	17.4	6.0	56.8	4.9	4,641

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
By-products of grains and seeds; miscellaneous concentrates—cont.							
Wheat middlings, standard, adulterated with bran	10.3	5.4	16.7	7.8	55.2	4.6	....
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1	66
Yeast and vinegar grains, dried	6.0	2.3	19.7	17.2	48.0	6.8	19
Milk and its products							
Cow's milk	87.2	0.7	3.5	....	4.9	3.7	....
Cow's milk, colostrum	74.5	1.6	17.6	....	2.7	3.6	42
Buttermilk	90.6	0.7	3.6	....	5.0	0.1	....
Buttermilk, dried	4.5	8.1	34.6	....	50.9	1.9	7
Buttermilk, semi-solid	65.0	2.7	13.4	....	15.9	3.0	....
Skim milk, centrifugal	90.1	0.7	3.8	....	5.2	0.2	....
Skim milk, gravity	90.4	0.7	3.3	....	4.7	0.9	96
Skim milk, dried	4.0	8.1	37.3	....	49.3	1.3	....
Whey	93.4	0.7	0.8	....	4.8	0.3	....
Ewe's milk	80.8	0.9	6.5	....	4.9	6.9	....
Mare's milk	90.6	0.4	2.0	....	5.9	1.1	72
Sow's milk	81.0	1.0	5.9	....	5.4	6.7	25
Slaughter-house by-products							
Dried blood	9.7	3.3	82.3	....	3.8	0.9	45
Fish meal	10.5	28.1	51.4	....	....	8.3	13
Fresh bone	30.4	21.1	19.7	....	3.8	25.0	4
Meat-and-bone meal, 30-40% ash	6.0	36.8	39.8	2.1	4.1	11.2	59
Meat-and-bone meal, over 40% ash	6.6	45.8	33.2	1.6	2.7	10.0	13
Pork cracklings	5.0	2.3	56.4	....	4.1	32.2	5
Poultry bone	7.3	61.7	24.3	....	3.6	3.1	24
Tankage, guaranteed 60% protein	7.9	15.3	60.4	5.3	3.7	7.4	621
Tankage, guaranteed 50–60% protein	9.0	18.4	51.7	6.6	3.9	10.4	47
Tankage, guaranteed 40–50% protein	8.5	21.7	46.0	3.3	4.6	15.9	29
Tankage, below 40% protein	9.1	24.7	36.9	4.1	10.8	14.4	137
DRIED ROUGHAGE							
Cured corn and sorghum forage, etc.							
Corn fodder (ears, if any, remaining), very dry, from barn or in arid districts	9.0	6.5	7.8	27.2	47.3	2.2	56
Corn fodder, medium in water	18.3	5.0	6.7	22.0	45.8	2.2	59
Corn fodder, high in water	39.3	3.6	4.8	16.7	34.2	1.4	23
Corn fodder, sweet corn	12.3	9.0	9.2	26.4	41.3	1.8	6
Corn leaves	23.4	6.2	7.1	22.1	39.4	1.8	28
Corn husks	24.7	2.5	2.9	24.9	44.2	0.8	17
Corn stalks	17.7	5.2	4.8	27.8	43.1	1.4	19
Corn stover (ears removed) very dry	9.4	5.8	5.9	30.7	46.6	1.6	183
Corn stover, medium in water	19.0	5.5	5.7	27.7	40.9	1.2	97
Corn stover, high in water	41.0	3.8	3.9	20.1	30.2	1.0	247
Corn tops	17.9	5.6	5.6	27.4	42.0	1.5	8
Broom-corn fodder	9.4	5.7	3.9	36.8	42.4	1.8	1
Durra fodder	10.1	5.2	6.4	24.1	51.4	2.8	3
Japanese cane fodder	6.8	2.0	1.4	20.6	67.3	1.9	1
Kafir fodder, dry	9.0	9.4	8.9	26.8	43.1	2.8	20
Kafir fodder, high in water	28.3	3.3	6.5	21.6	37.6	2.7	2
Kafir stover, dry	16.3	8.3	5.1	27.4	41.2	1.7	3
Kafir stover, high in water	27.3	7.3	3.8	23.7	36.6	1.3	4
Milo fodder, dry	11.1	9.9	12.0	18.4	44.1	4.5	5
Milo fodder, high in water	39.1	3.1	3.7	17.5	34.3	2.3	7
Milo stover, high in water	35.5	6.7	2.3	20.6	34.1	0.8	1

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cured corn and sorghum forage, etc.—cont.							
Sorghum fodder, dry	9.7	7.8	7.4	26.1	45.9	3.1	22
Sorghum fodder, high in water	37.4	3.1	3.9	17.8	35.0	2.8	11
Sorghum bagasse, dried	11.3	2.9	3.4	30.5	50.5	1.4	2
Sugar-cane bagasse	10.2	5.6	3.3	34.6	39.2	7.1	1
Hay from the grasses, etc.							
Bent grass, Canada, or blue joint, *Calamagrostis Canadensis*	6.7	6.8	7.6	34.7	41.8	2.4	10
Bermuda grass	9.7	7.6	7.1	25.6	48.2	1.8	14
Black grass, *Juncus Gerardi*	10.3	7.3	7.5	25.1	47.3	2.5	21
Bluegrass, Canada	10.7	5.8	6.6	28.2	46.4	2.3	10
Bluegrass, Kentucky, all analyses	13.2	6.6	8.3	28.3	40.7	2.9	26
Bluegrass, Kentucky, in milk	12.4	5.9	8.5	23.4	47.0	2.8	2
Bluegrass, Kentucky, ripe	12.0	7.5	7.0	29.3	40.7	3.5	5
Bluegrasses, native western	8.1	8.0	11.2	29.8	39.9	3.0	7
Brome grass, smooth	8.5	7.7	9.9	31.3	40.2	2.4	8
Bluestem grasses, *Andropogon* spp	6.9	5.5	4.9	34.2	46.7	1.8	10
Buffalo grass, *Bulbilis dactyloides*	7.0	11.5	7.0	26.1	46.6	1.8	7
Bunch grasses, miscellaneous	7.0	9.2	6.0	30.6	45.4	1.8	9
Carpet grass	7.9	10.2	7.0	31.8	40.9	2.2	1
Chess, or cheat, *Bromus secalinus*	8.4	7.9	7.2	28.0	46.2	2.3	10
Crab grass	9.5	8.5	8.0	28.7	42.9	2.4	9
Crow-foot grass, *Eleusine* spp	9.5	7.9	8.6	27.4	44.4	2.2	10
Fescue, meadow	11.7	7.0	6.8	30.4	42.1	2.0	21
Fescues, native, *Festuca* spp	4.9	5.8	8.9	33.5	44.8	2.1	9
Fowl meadow grass	11.1	7.2	9.8	28.8	40.4	2.7	5
Foxtails, miscellaneous	6.8	10.1	9.3	28.6	42.6	2.6	14
Gama grass, *Tripsacum dactyloides*	11.8	6.2	6.7	30.4	43.1	1.8	3
Grama grasses, *Bouteloua* spp	6.6	9.0	6.4	28.7	47.6	1.7	15
Hair grasses, miscellaneous	6.6	6.8	8.3	31.2	44.9	2.2	17
Johnson grass	10.1	7.5	6.6	30.2	43.5	2.1	17
Millet, barnyard	13.5	8.2	8.3	27.6	40.8	1.6	14
Millet, common, or Hungarian	14.3	6.3	8.3	24.0	44.3	2.8	56
Millet, German	8.7	6.9	8.0	27.3	46.5	2.6	22
Millet, hog, or broom-corn	9.3	5.9	8.8	21.3	52.2	2.5	5
Millet, pearl, or cat-tail	12.8	9.0	6.7	33.0	36.8	1.7	6
Millet, wild, or Indian	6.7	6.9	10.6	30.7	42.7	2.4	7
Mixed grasses	12.8	5.6	7.6	28.8	42.7	2.5	359
Mixed grasses, rowen	13.6	6.5	12.3	24.2	40.1	3.3	49
Natal grass, *Tricholaena rosea*	9.8	5.0	7.4	36.8	39.2	1.8	....
Needle grasses, *Stipa* spp	5.3	5.5	7.8	34.0	45.6	1.8	9
Nerved manna grass, *Panicularia nervata*	6.2	8.5	8.0	28.6	46.8	1.9	4
Oat grass, tall, or meadow oat grass, *Arrhenatherum elatius*	11.8	6.1	8.0	29.4	42.1	2.6	13
Old witch grass, *Panicum capillare*	7.1	10.1	10.6	24.3	45.7	2.2	3
Orchard grass	11.6	6.9	7.9	30.3	40.4	2.9	46
Para grass	9.8	6.6	4.6	33.6	44.5	0.9	3
Panic grasses, *Panicum* spp	7.9	7.1	8.3	29.5	44.9	2.3	21
Prairie hay, western	6.5	7.7	8.0	30.5	44.7	2.6	42
Quack, or couch grass, *Agropyron repens*	5.9	7.3	7.3	36.5	41.0	2.0	4
Rescue grass	9.8	8.1	9.8	24.6	44.5	3.2	3
Red top, all analyses	9.8	6.8	7.4	28.7	45.0	2.3	40
Red top, in bloom	8.0	8.1	7.2	29.9	44.7	2.1	15

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the grasses, etc,—cont.							
Reed bent grass, *Calamagrostis purpurascens*	5.9	5.1	10.2	31.2	45.3	2.3	3
Reed canary grass, *Phalaris arundinacea*	9.6	7.9	7.9	29.0	42.9	2.7	10
Reed grasses, miscellaneous western	7.0	7.0	6.2	33.3	44.3	2.2	8
Reed meadow grass, or manna, *Panicularia Americana*	6.7	9.7	9.3	29.5	42.9	1.9	7
Rhode Island bent, *Agrostis canina*	11.5	6.6	6.6	29.5	42.8	3.0	2
Rye grass, Italian	11.4	7.5	8.1	27.8	43.3	1.9	7
Rye grass, perennial	12.0	8.1	9.2	24.2	43.4	3.1	14
Rushes, western, *Juncus* spp	5.7	7.6	10.2	29.2	45.5	1.8	28
Salt grasses, miscellaneous	5.3	12.6	8.1	30.5	41.5	2.0	4
Sedges, western, *Carex* spp	5.2	6.8	11.2	28.2	46.3	2.3	45
Sedges, eastern, *Carex* spp	9.3	7.4	6.1	29.2	46.3	1.7	3
Spear grasses, *Poa* spp	5.5	5.8	7.6	30.0	49.0	2.1	33
Sudan grass	11.6	7.0	8.2	26.9	44.7	1.6	44
Swamp grasses	9.8	7.7	7.7	28.2	44.3	2.3	37
Sweet vernal grass, *Anthoxanthum odoratum*	9.3	9.3	12.4	21.7	42.7	4.6	2
Teosinte	10.6	10.3	9.1	26.4	41.7	1.9	4
Timothy, all analyses	11.6	4.9	6.2	29.8	45.0	2.5	221
Timothy, before bloom	7.2	6.6	9.8	28.1	45.1	3.2	7
Timothy, early to full bloom	12.8	4.6	6.3	29.5	44.2	2.6	50
Timothy, late bloom to early seed	14.9	4.5	5.5	28.3	44.0	2.8	21
Timothy, nearly ripe	12.5	4.3	5.2	30.7	45.1	2.2	28
Timothy, rowen	15.1	6.9	14.4	24.3	34.9	4.4	3
Wheat grass, common, *Agropyron glaucum*	7.3	6.9	6.5	27.4	49.4	2.5	4
Wheat grasses, miscellaneous, *Agropyron* spp	6.4	6.2	7.1	30.2	47.7	2.4	19
Wheat grass, western, *Agropyron occidentale*	5.9	7.0	7.7	32.7	44.4	2.3	13
Wild barley, or foxtail, *Hordeum jubatum*	7.5	8.8	7.0	27.4	47.3	2.0	5
Wild oat, *Avena fatua*	7.9	6.4	8.0	30.1	44.8	2.8	13
Wild rye, *Elymus Canadensis*	10.8	7.3	7.1	26.1	46.8	1.9	10
Hay from the smaller cereals							
Barley hay, common	7.4	6.4	7.0	29.7	47.3	2.2	5
Barley hay, bald	8.7	6.9	7.4	21.9	53.0	2.1	5
Emmer hay	7.7	9.3	10.0	33.6	37.3	2.1	4
Oat hay	12.0	6.8	8.4	28.3	41.7	2.8	72
Rye hay, all analyses	8.1	5.1	6.7	37.5	40.5	2.1	12
Rye hay, heading out to in bloom	8.2	5.8	9.8	33.9	39.7	2.6	3
Wheat hay	8.1	6.4	6.2	24.7	52.6	2.0	12
Hay from the legumes							
Alfalfa, all analyses	8.6	8.6	14.9	28.3	37.3	2.3	250
Alfalfa, first cutting	8.5	8.8	13.9	30.9	36.2	1.7	46
Alfalfa, second cutting	7.3	9.0	14.7	31.9	35.4	1.7	33
Alfalfa, third cutting	8.9	9.5	14.6	28.4	36.8	1.8	17
Alfalfa, fourth cutting	16.0	7.8	15.9	24.6	34.0	1.7	3
Alfalfa, before bloom	6.2	10.0	22.0	20.5	37.1	4.2	11
Alfalfa, in bloom	7.5	10.0	15.0	30.2	35.5	1.8	31
Alfalfa, in seed	10.4	7.0	12.2	27.6	40.3	2.5	10
Alfalfa, variegated, or sand lucerne	15.2	8.3	14.2	27.8	32.3	2.2	4
Alfalfa meal	8.8	9.0	14.3	30.1	35.8	2.0	176
Alfalfa leaves	6.6	13.6	22.5	12.7	41.2	3.4	6

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the legumes—cont.							
Alfalfa stems	5.6	4.9	6.3	54.4	27.9	0.9	2
Bean, whole plant	12.6	3.5	22.5	4.4	55.2	1.8	....
Beggarweed	9.1	8.4	15.4	27.5	37.3	2.3	11
Clover, alsike, all analyses	12.3	8.3	12.8	25.7	38.4	2.5	32
Clover, alsike, in bloom	12.6	7.7	13.2	26.4	37.0	3.1	5
Clover, bur	7.0	10.8	19.2	23.0	37.0	3.0	11
Clover, crimson, or scarlet	10.6	8.8	14.1	27.3	36.9	2.3	18
Clover, Egyptian, or berseem, *Trifolium Alexandrinum*	7.5	9.5	14.4	23.2	43.0	2.4	2
Clover, mammoth red	18.7	6.2	10.8	27.0	34.2	3.1	19
Clover, red, all analyses	12.9	7.1	12.8	25.5	38.7	3.1	76
Clover, red, before bloom	10.4	7.2	18.7	18.3	41.8	3.6	2
Clover, red, in bloom	13.9	7.4	13.1	23.1	39.1	3.4	18
Clover, red, after bloom	22.1	6.0	11.6	21.9	33.8	4.6	5
Clover, sweet, white	8.6	7.2	14.5	27.4	40.1	2.2	18
Clover, sweet, yellow	8.7	6.0	13.4	38.8	31.5	1.6	1
Clover, white	8.1	8.0	16.2	23.2	41.6	2.9	7
Clover meal	8.5	7.2	13.7	25.9	42.4	2.3	12
Clover rowen	14.8	7.3	16.5	20.4	37.3	3.7	2
Cowpea, all analyses	9.7	11.9	19.3	22.5	34.0	2.6	35
Cowpea, before bloom	7.8	17.3	26.2	20.6	25.5	2.6	13
Cowpea, in bloom to early pod	10.6	10.2	18.5	21.0	36.4	3.3	6
Cowpea, ripe	10.0	6.4	10.1	29.2	41.8	2.5	3
Flat pea, *Lathyrus silvestris*, var. *Wagneri*	7.7	6.7	22.7	27.7	32.0	3.2	5
Kudzu vine	6.7	7.4	18.3	30.2	34.5	2.9	2
Lespedeza, or Japan clover	11.8	5.8	12.1	25.9	41.6	2.8	14
Lupines, *Lupinus* spp	7.8	8.8	15.8	20.8	43.5	3.3	13
Pea, field	11.1	7.9	15.1	24.5	37.9	3.5	30
Pea, field, without peas	9.4	6.6	9.5	27.7	45.2	1.6	3
Peanut vine, mowed	18.1	9.0	9.7	20.7	38.4	4.1	10
Peanut vine, pulled, nuts removed	9.5	8.2	9.6	24.3	45.3	3.1	10
Peanut vine, with nuts	7.8	6.6	13.1	24.5	34.7	13.3	5
Sanfoin, *Onobrychis viciaefolia*	15.9	7.1	10.5	19.7	44.2	2.6	5
Serradella	9.7	12.3	15.7	19.6	40.2	2.5	5
Soybean hay	8.6	8.6	16.0	24.9	39.1	2.8	23
Trefoil, yellow, or black medic, *Medicago lupulina*	11.2	10.9	16.9	14.8	43.2	3.0	2
Velvet bean	7.2	7.4	16.4	27.5	38.4	3.1	4
Vetch, common	7.1	8.2	17.3	26.2	38.7	2.5	3
Vetch, hairy	12.3	8.6	19.9	24.8	31.6	2.8	15
Vetch, kidney, *Anthyllis vulneraria*	9.7	11.2	12.1	26.5	38.9	1.6	4
Vetches, wild	6.6	8.2	17.0	26.0	39.8	2.4	12
Hay from mixed legumes and grasses							
Clover and mixed grasses	10.1	6.4	9.9	28.5	42.3	2.8	34
Clover and timothy	12.2	6.1	8.6	29.9	40.8	2.4	52
Clover mixed rowen	13.0	5.8	11.8	27.9	38.6	2.9	11
Cowpeas and millet	9.7	14.8	13.7	27.6	32.0	2.2	2
Peas and oats	16.6	7.3	11.4	25.6	36.5	2.6	30
Peas, oats, and barley	16.5	6.0	12.6	29.5	32.4	3.0	1
Vetch and oats	15.7	6.7	10.6	27.2	37.3	2.5	8
Vetch and wheat	15.0	6.8	14.5	27.2	34.4	2.1	4

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Straw and chaff from the cereals							
Barley straw	14.2	5.7	3.5	36.0	39.1	1.5	97
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3	3
Flax shives	7.2	7.0	7.2	42.5	32.9	3.2	11
Millet straw	14.2	5.2	3.6	35.8	39.7	1.5	6
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Oat chaff	8.2	11.5	5.9	25.7	46.3	2.4	4
Rice straw	7.5	14.5	3.9	33.5	39.2	1.4	13
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2	7
Wheat straw	8.4	5.2	3.1	37.4	44.4	1.5	27
Wheat straw from rusted grain	8.1	6.4	8.7	40.9	34.6	1.3	8
Wheat chaff	14.4	7.2	4.2	28.0	44.8	1.4	1
Legume straws							
Bean straw	10.5	7.2	7.3	30.8	42.9	1.3	5
Pea straw, field	9.8	5.3	6.1	33.2	44.0	1.6	20
Crimson clover straw	12.3	7.0	7.5	38.8	32.9	1.5	3
Cowpea straw	8.5	5.4	6.8	44.5	33.6	1.2	1
Horse bean straw	12.1	8.4	8.6	36.4	33.1	1.4	2
Soybean straw	11.9	6.8	5.6	36.8	37.2	1.7	8
Miscellaneous dry roughages							
Alfilaria, *Erodium cicutarium*	11.1	11.4	11.1	23.0	40.2	3.2	3
Artichoke tops	25.8	7.0	4.2	22.0	40.1	0.9	1
Brush feed	5.0	2.8	5.4	46.5	37.9	2.4	1
Burnet, *Sanguisorba minor*	11.1	8.8	13.0	20.7	42.5	3.9	5
Daisy, field	9.3	10.2	14.1	22.0	40.1	4.3	4
Furze	5.5	7.0	11.6	38.5	35.4	2.0	1
Greasewood	4.6	14.4	19.8	24.5	34.3	2.4	1
Lamb's quarter	9.7	16.5	24.0	12.3	33.2	4.3	1
Prickly comfrey	7.9	22.0	25.5	8.7	32.8	3.1	1
Purslane	11.9	22.9	22.3	14.2	24.5	4.2	1
Rape	11.3	14.5	18.9	12.8	39.2	3.3	5
Russian thistle	5.8	15.9	18.2	25.0	32.1	3.0	1
Saltbushes, *Atriplex* spp.	6.6	17.4	13.5	22.6	38.4	1.5	25
Spurrey, *Spergula arvensis*	7.9	10.4	11.3	19.1	46.8	4.5	7
Sweet potato vines	11.3	9.2	12.5	20.2	43.5	3.3	6
FRESH GREEN ROUGHAGE							
Corn and the sorghums							
Corn fodder, all analyses	78.1	1.2	1.9	5.2	13.0	0.6	708
Corn fodder, dent, all analyses	76.9	1.2	1.9	5.5	13.9	0.6	260
Corn fodder, dent, in tassel	85.1	1.1	1.6	4.3	7.6	0.3	9
Corn fodder, dent, in milk	80.1	1.1	1.6	4.9	11.7	0.6	16
Corn fodder, dent, dough to glazing	74.9	1.1	2.1	5.6	15.4	0.9	15
Corn fodder, dent, kernels glazed	73.8	1.2	2.0	6.2	16.2	0.6	26
Corn fodder, dent, kernels ripe	65.2	1.4	2.7	7.4	22.3	1.0	7
Corn fodder, flint, all analyses	79.3	1.0	1.9	4.6	12.6	0.6	94
Corn fodder, flint, in tassel	89.4	0.8	1.4	3.2	4.8	0.4	4
Corn fodder, flint, in milk	85.0	0.8	1.5	3.6	8.6	0.5	3
Corn fodder, flint, kernels glazed	79.0	1.1	1.9	4.2	12.9	0.9	15
Corn fodder, flint, kernels ripe	72.1	1.3	2.4	6.1	17.0	1.1	1
Corn fodder, pop	83.1	1.0	1.3	6.0	8.2	0.4	2
Corn fodder, sweet, before milk stage	90.0	1.0	1.0	2.5	5.2	0.3	5
Corn fodder, sweet, roasting ears or later	79.7	1.2	1.9	4.4	12.2	0.6	55
Corn fodder, sweet, ears removed	78.5	1.3	1.6	5.6	12.6	0.4	3
Corn leaves and tops	84.1	1.2	1.9	4.4	7.8	0.6	2
Corn husks	63.5	1.5	1.8	11.9	20.9	0.4	22

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn and the sorghums—cont.							
Corn leaves	68.9	3.2	3.2	8.6	15.4	0.7	22
Corn stalks, stripped	73.6	1.1	1.3	9.1	14.5	0.4	42
Corn stover, green (ears removed)	77.3	1.4	1.3	6.0	13.6	0.4	18
Broom-corn fodder	77.1	1.7	2.0	8.6	10.1	0.5	1
Durra fodder	77.6	1.8	2.0	6.2	11.8	0.6	3
Kafir fodder, all analyses	76.4	1.9	2.4	6.6	12.0	0.7	56
Kafir fodder, heads just showing	80.1	1.3	1.6	6.5	10.1	0.4	5
Milo fodder	77.3	1.4	1.8	7.0	12.1	0.4	9
Sorghum fodder, sweet	75.1	1.4	1.5	7.0	14.0	1.0	94
Sugar cane	78.3	1.4	0.9	6.2	12.2	1.0	8
Sweet corn ears, including husks	62.2	0.9	3.8	4.3	26.2	2.6	3
Fresh green grass							
Bent grass, Canada, or bluejoint, *Calamagrostis Canadensis*	55.4	4.1	4.1	15.2	20.0	1.2	3
Bermuda grass	66.8	2.3	3.0	8.0	18.9	1.0	2
Bluegrass, Canada	66.8	2.6	3.0	10.3	16.1	1.2	9
Bluegrass, Kentucky, all analyses	68.4	2.8	4.1	8.7	14.8	1.2	32
Bluegrass, Kentucky, before heading	76.2	2.7	5.3	5.2	9.3	1.3	7
Bluegrass, Kentucky, headed out	63.6	3.7	4.9	10.9	15.6	1.3	4
Bluegrass, Kentucky, after bloom	56.4	4.1	3.4	13.2	21.6	1.3	2
Bluegrasses, native	54.7	2.5	3.2	15.0	23.3	1.3	5
Brome grass, smooth	67.0	2.9	4.2	9.3	15.1	1.5	35
Brome grasses, miscellaneous	63.7	3.2	4.5	11.9	15.7	1.0	17
Bluejoint grasses, western, *Andropogon* spp	61.1	2.8	2.6	12.8	19.8	0.9	5
Bluestem grasses, *Andropogon* spp	68.4	2.4	3.0	10.5	14.2	1.5	16
Bunch grasses, miscellaneous	50.6	4.2	4.3	15.8	23.9	1.2	1
Chess, or cheat, *Bromus secalinus*	60.4	1.8	3.2	13.0	20.5	1.1	1
Crab grass	69.1	4.3	2.7	9.1	13.8	1.0	6
Fescue, meadow	69.5	2.4	3.0	10.1	14.0	1.0	33
Fescues, native, *Festuca* spp	64.0	2.5	3.5	12.5	16.7	0.8	10
Guinea grass, *Panicum maximum*	71.5	2.6	2.2	10.9	12.1	0.7	1
Grama grass, *Bouteloua* spp	63.9	2.5	3.3	12.7	16.7	0.9	3
Johnson grass	70.9	2.0	2.5	9.3	14.4	0.9	14
Meadow foxtail	70.4	2.7	3.6	8.0	14.1	1.2	4
Millet, barnyard	78.7	1.6	1.7	6.7	10.7	0.6	43
Millet, common, or Hungarian	72.4	2.1	2.9	8.4	13.3	0.9	19
Millet, hog, or broom-corn	75.3	1.8	2.0	7.4	12.9	0.6	11
Millet, pearl, or cat-tail	81.3	1.6	1.8	6.2	8.8	0.3	5
Mixed grasses, immature	70.3	3.0	5.1	6.3	13.8	1.5	6
Mixed grasses, at haying stage	69.2	1.8	3.0	10.6	14.1	1.3	7
Oat grass, tall, or meadow oat grass, *Arrhenatherum elatius*	69.7	2.0	2.6	10.5	14.3	0.9	31
Orchard grass	70.8	2.5	2.9	9.8	12.9	1.1	57
Para grass	72.8	2.4	1.7	9.2	13.4	0.5	2
Quack grass, *Agropyron repens*	75.0	2.5	3.8	7.0	10.5	1.2	6
Rescue grass	69.4	2.4	3.8	8.6	14.8	1.0	8
Red top	60.7	2.7	3.1	12.2	20.2	1.1	16
Reed canary grass, *Phalaris arundinacea*	63.0	2.9	3.6	10.9	18.5	1.1	5
Reed meadow grass, or manna, *Panicularia Americana*	69.3	2.5	2.8	10.0	14.8	0.6	3
Rhode Island bent grass, *Agrostis canina*	67.3	2.6	2.9	10.6	15.9	0.7	3
Rowen, mixed	71.8	2.4	4.7	7.3	12.3	1.5	6
Rye grass, Italian	72.9	2.5	3.1	6.8	13.4	1.3	25

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Fresh green grass—cont.							
Rye grass, perennial	73.4	2.4	3.0	6.7	13.2	1.3	25
Rushes, western, *Juncus* spp.	68.9	2.2	3.4	9.8	15.1	0.6	11
Sedges, western, *Carex* spp.	61.5	3.2	3.8	11.4	19.0	1.1	15
Spear grasses, miscellaneous	56.4	2.7	3.3	14.7	21.9	1.0	13
Sudan grass	77.5	1.6	1.8	7.5	10.9	0.7	3
Sweet vernal grass, *Anthoxanthum odoratum*	68.8	2.0	2.6	9.7	15.9	1.0	6
Teosinte	78.7	2.0	1.7	6.7	10.4	0.5	19
Timothy, all analyses	62.5	2.2	3.1	11.7	19.3	1.2	88
Timothy, before bloom	75.8	1.7	2.5	7.3	12.0	0.7	5
Timothy, in bloom	67.9	2.0	2.7	10.4	16.1	0.9	15
Timothy, in seed	53.6	2.3	3.1	15.3	24.4	1.3	13
Timothy, mountain, *Phleum alpinum*	62.5	1.8	3.0	12.9	18.8	1.0	3
Wheat grasses, miscellaneous, *Agropyron* spp.	54.7	3.2	4.0	15.7	21.1	1.3	15
Wild barley, or foxtail, *Hordeum jubatum*	64.3	3.5	4.9	11.8	14.1	1.4	9
Wild oats, *Avena fatua*	63.4	2.7	2.6	8.6	21.3	1.4	5
Wild rye, *Elymus Canadensis*	76.7	2.2	3.7	7.5	8.9	1.0	5
Green fodder from the smaller cereals							
Barley fodder	76.8	2.1	3.3	6.0	11.0	0.8	15
Buckwheat, Japanese	63.4	3.6	4.6	8.0	19.5	0.9	1
Oat fodder	73.9	2.1	3.2	7.8	11.9	1.1	22
Oat fodder, 8 in. high	87.0	1.6	4.9	1.7	4.0	0.8	1
Rye fodder	78.7	1.7	2.6	7.3	9.0	0.7	38
Rye fodder, 5 in. high	81.9	2.2	6.5	2.0	6.5	0.9	1
Wheat fodder, all analyses	72.6	2.7	3.6	7.5	12.8	0.8	15
Wheat fodder, 5 in. high	75.8	3.0	6.5	3.9	10.1	0.7	1
Green legumes							
Alfalfa, all analyses	74.7	2.4	4.5	7.0	10.4	1.0	143
Alfalfa, before bloom	80.1	2.3	4.7	4.2	7.9	0.8	11
Alfalfa, in bloom	74.1	2.5	4.4	7.8	10.4	0.8	27
Alfalfa, after bloom	70.2	2.2	2.9	12.8	11.3	0.6	6
Beggarweed	72.9	3.2	4.2	7.5	11.7	0.5	3
Clover, alsike	75.7	2.4	4.1	6.5	10.7	0.6	17
Clover, alsike, in bloom	78.5	2.2	3.5	5.9	9.3	0.6	12
Clover, bur	79.2	2.3	5.1	3.9	7.8	1.7	3
Clover, crimson	82.6	1.7	3.0	4.7	7.4	0.6	22
Clover, mammoth red	74.9	2.3	4.0	7.3	11.0	0.5	7
Clover, red, all analyses	73.8	2.1	4.1	7.3	11.7	1.0	85
Clover, red, in bloom	72.5	2.0	4.1	8.2	12.1	1.1	36
Clover, red, rowen	65.6	2.5	5.3	9.1	16.2	1.3	7
Clover, sweet	75.6	2.1	4.4	7.0	10.2	0.7	18
Clover, white	78.2	2.7	4.6	4.2	9.5	0.8	6
Cowpeas	83.7	2.0	3.0	3.8	7.0	0.5	144
Flat pea, *Lathyrus silvestris*, var.	77.5	1.6	5.7	6.4	8.0	0.8	8
Jack bean, *Canavalia ensiformis*	76.8	2.7	5.2	6.4	8.4	0.5	1
Horse bean	82.4	2.0	3.6	4.2	7.3	0.5	5
Lupines	82.6	1.6	3.4	4.6	7.2	0.6	9
Peas, field, Canada	83.4	1.6	3.6	4.0	6.9	0.5	33
Peas, field, miscellaneous	81.2	1.6	3.2	5.3	8.1	0.6	16
Kudzu vine	69.4	2.2	5.5	8.3	13.6	1.0	1
Lespedeza, or Japan clover	63.4	3.5	6.7	10.7	14.7	1.0	1
Sanfoin, *Onobrychis viciaefolia*	74.4	2.4	3.8	6.2	12.4	0.8	4
Serradella	79.8	3.0	2.9	4.8	8.8	0.7	8

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green legumes—cont.							
Soybeans, all analyses	76.4	2.4	4.1	6.3	9.8	1.0	145
Soybeans, in bloom	79.2	2.3	3.9	5.8	8.2	0.6	8
Soybeans, in seed	75.8	2.4	4.0	6.4	10.4	1.0	21
Trefoil, yellow, or black medic, *Medicago lupulina*	77.3	2.3	4.5	5.6	9.5	0.8	2
Velvet bean	82.1	2.0	3.5	5.1	6.6	0.7	1
Vetch, common	79.6	2.1	3.8	5.5	8.5	0.5	14
Vetch, kidney, *Anthyllis vulneraria*	72.3	3.2	3.7	8.3	12.0	0.5	5
Vetch, hairy	81.8	2.2	4.2	5.0	6.3	0.5	21
Vetches, wild	75.4	2.1	5.1	6.9	10.0	0.5	6
Mixed legumes and grasses							
Clover and mixed grasses	72.7	1.6	3.0	8.5	13.3	0.9	19
Cowpeas and corn	80.0	1.8	2.1	5.3	10.4	0.4	1
Cowpeas and oats	78.2	2.2	4.5	5.7	8.5	0.9	3
Cowpeas and sorghum	81.3	1.7	1.5	5.5	9.5	0.5	2
Peas and millet	80.3	2.6	2.6	6.6	6.6	1.3	3
Peas and barley	79.8	1.7	3.6	5.2	8.9	0.8	11
Peas and oats	77.4	2.0	3.2	6.3	10.1	1.0	46
Peas, oats, and rape	82.1	2.7	3.1	4.3	7.0	0.8	3
Soybeans and corn	76.2	1.7	2.7	5.4	13.2	0.8	9
Soybeans and kafir	82.9	2.1	2.0	6.2	6.2	0.6	1
Vetch and barley	80.0	1.2	2.8	6.5	9.0	0.5	2
Vetch and oats	73.5	2.3	3.8	7.5	12.0	0.9	15
Vetch and wheat	77.3	1.6	3.3	7.1	10.1	0.6	5
Roots, tubers, etc.							
Artichoke	79.5	1.7	2.0	0.8	15.9	0.1	22
Beet, common	87.0	1.5	1.6	0.9	8.9	0.1	23
Beet, sugar	83.6	1.1	1.6	1.0	12.6	0.1	86
Carrot	88.3	1.2	1.2	1.1	8.0	0.2	18
Cassava	67.4	1.0	1.1	1.4	28.8	0.3	3
Chufa	79.5	0.4	0.7	2.2	10.5	6.6	....
Mangel	90.6	1.0	1.4	0.8	6.1	0.1	38
Onion	87.6	0.5	1.3	0.7	9.6	0.3	6
Parsnip	83.4	1.3	1.7	1.3	11.9	0.4	2
Potato	78.8	1.1	2.2	0.4	17.4	0.1	465
Rutabaga	89.1	1.0	1.2	1.4	7.0	0.3	10
Sweet potato	68.8	1.1	1.8	1.3	26.4	0.6	145
Turnip	90.5	0.9	1.4	1.1	5.9	0.2	20
Miscellaneous green forages							
Alfilaria, *Erodium cicutarium*	83.7	3.0	3.2	2.9	6.8	0.4	2
Apple	81.8	0.4	0.5	1.3	15.6	0.4	9
Apple pomace	76.7	1.0	1.6	4.6	14.5	1.6	17
Burnet	80.1	2.0	3.0	4.6	9.6	0.7	3
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3	5
Cabbage waste, outer leaves	85.9	3.1	2.7	2.8	5.1	0.4	2
Cactus, cane, entire plant	89.6	1.7	0.9	1.1	6.5	0.2	5
Cactus, cane, fruit	81.4	2.7	1.5	3.2	10.4	0.8	35
Cactus, cane, stems	78.3	3.8	1.5	3.4	12.6	0.4	42
Cactus, prickly pear	83.5	3.4	0.8	2.3	9.7	0.3	94
Cactus, prickly pear, old joints	83.6	3.2	0.6	2.5	9.8	0.3	4
Cactus, prickly pear, young joints	87.1	2.6	0.9	1.2	7.8	0.4	5
Kale	88.7	1.9	2.4	1.5	5.0	0.5	12
Kohlrabi	91.0	1.3	2.0	1.3	4.3	0.1	2
Melon, pie, or stock	93.9	0.4	0.7	1.4	3.4	0.2	3

TABLE I. Average percentage composition of American feeding stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—cont.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Miscellaneous green forages—cont.							
Mustard, white, *Brassica alba*	86.0	2.1	4.1	1.7	5.5	0.6	2
Potato pomace, wet	91.7	0.3	0.7	0.9	6.3	0.1	2
Prickly comfrey	87.2	2.3	2.5	1.8	5.9	0.3	20
Pumpkin, field	91.7	0.9	1.4	1.3	4.2	0.5	4
Purslane	89.7	1.9	2.2	1.5	4.4	0.3	3
Rape	83.3	2.2	2.9	2.6	8.4	0.6	37
Russian thistle	79.6	3.8	3.0	4.8	8.3	0.5	5
Saltbush, Australian	76.7	5.4	3.7	4.4	9.4	0.4	7
Saltbushes, miscellaneous	75.7	5.1	3.9	4.2	10.8	0.3	3
Sugar beet leaves	88.4	1.8	1.9	1.1	6.5	0.3	5
Sugar beet tops	88.6	2.0	2.6	1.2	5.3	0.3	4
Sunflower, Russian, whole plant	83.4	1.7	1.4	4.8	8.1	0.6	10
Turnip tops	85.0	3.0	2.8	1.5	7.3	0.4	5
SILAGE							
Silage from corn, the sorghums, etc.							
Corn, well matured, recent analyses	73.7	1.7	2.1	6.3	15.4	0.8	121
Corn, immature	79.0	1.4	1.9	5.8	11.3	0.6	53
Corn, early analyses	76.9	1.4	1.9	6.2	12.7	0.9	372
Corn, from frosted corn	74.7	1.8	2.2	6.1	14.4	0.8	10
Corn stover silage, from cured stover	79.4	1.3	1.5	6.8	10.5	0.6	5
Darso	73.1	1.5	1.9	6.5	16.7	0.3	1
Durra	79.7	1.9	1.2	7.0	9.5	0.7	3
Japanese cane	77.6	2.0	1.5	8.6	9.7	0.6	1
Kafir	69.2	2.5	1.8	9.9	15.5	1.1	3
Sorghum, sweet	77.2	1.6	1.5	6.9	11.9	0.9	30
Sugar-cane tops	76.6	1.9	1.3	8.0	11.8	0.4	1
Miscellaneous silage							
Alfalfa, wilted before being ensiled	46.0	5.3	10.0	14.2	22.0	2.5	4
Alfalfa, high in water	75.0	3.2	3.9	8.8	7.5	1.6	3
Apple pomace	79.4	1.0	1.6	4.5	12.2	1.3	14
Barley	75.0	2.6	2.6	9.4	9.4	1.0	2
Clover, red	75.6	2.2	3.9	6.6	10.4	1.3	72
Corn and clover	71.4	2.2	3.3	7.7	14.5	0.9	1
Corn and rye	80.6	1.4	2.1	7.2	7.5	1.2	1
Corn and soybean	74.9	2.0	2.6	6.7	12.8	1.0	16
Cowpea	78.8	2.3	3.1	6.1	8.9	0.8	11
Cowpea and soybean	71.5	3.5	3.4	8.6	11.9	1.1	2
Grasses, mixed	69.3	2.5	2.3	9.9	14.6	1.4	5
Millet	68.4	3.4	2.8	9.7	14.6	1.1	6
Millet, barnyard, and soybean	79.0	2.8	2.8	7.2	7.2	1.0	9
Mung bean, nearly mature	76.7	1.2	3.1	9.8	8.0	1.2	1
Oat	71.7	1.9	2.0	9.8	13.3	1.3	2
Oat and pea	69.9	3.0	4.1	10.0	11.7	1.3	9
Pea, field	72.1	2.6	3.8	7.8	12.5	1.2	8
Pea-cannery refuse	76.8	1.3	2.8	6.5	11.3	1.3	....
Rye	73.1	2.2	3.3	9.6	11.0	0.8	4
Sorghum and cowpea	67.7	2.2	2.4	8.5	18.2	1.0	8
Soybean	72.8	3.5	4.2	7.9	10.1	1.5	12
Sudan grass	74.7	1.8	2.4	8.6	11.8	0.7	5
Sugar beet pulp	90.0	0.3	1.5	3.1	4.7	0.4	1
Sugar beet tops	71.2	13.0	3.2	2.4	9.6	0.6	11
Sunflower	78.1	2.2	2.0	6.4	10.2	1.1	33
Velvet bean	76.4	1.1	4.3	8.0	9.0	1.2	1
Vetch	69.9	2.4	3.5	9.8	13.4	1.0	6

Table II. Average Digestibility of American Feeding Stuffs, with Additions from the German Tables

The coefficients marked "H & M" in this table have been compiled by the authors from the digestion trials reported by the State Experiment Stations and the United States Department of Agriculture. Those marked "L" are from the compilation by Lindsey and colleagues of the Massachusetts Station, given in *Compilation of Analyses*, published by the Station in 1919. To render the table more complete, additions marked "M" have been made from the German tables given in Mentzel and Lengerke's *Landwirtschaftliche Kalender*.

This table is fully protected by copyright.

A. Experiments with Ruminants

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
Concentrates		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grains and seeds							
Barley	15	88	78	56	92	78	H & M
Barley, ground	2	89	88	70	93	86	H & M
Buckwheat	2	71	75	24	76	100	M
Corn, dent, ground	12	90	74	57	94	93	H & M
Corn-and-cob meal	3	79	52	45	88	84	H & M
Cotton seed	2	66	68	76	50	87	H & M
Cotton seed, roasted	2	56	47	66	51	72	H & M
Cowpeas	2	87	82	64	93	74	H & M
Darso grain, in unbalanced ration	2	73	56	..	84	69	
Emmer	15	..	80	64	89	88	H & M
Flax seed	7	77	91	60	55	86	M
Horse beans	30	..	87	58	91	83	M
Kafir, with legume hay	2	..	81	55	92	76	H & M
Kafir, in unbalanced ration	15	50	47	44	51	51	H & M
Kafir heads, with legume hay	2	..	63	61	80	74	H & M
Kafir heads, in unbalanced ration	8	34	32	35	36	40	H & M
Milo maize, in unbalanced ration	3	80	57	100	84	88	H & M
Millet seed, whole	6	..	59	41	84	80	H & M
Millet seed, ground	6	..	71	53	92	73	H & M
Oats	17	70	78	35	81	87	H & M
Pea meal	2	87	83	26	94	55	H & M
Rice meal	2	74	62	..	92	91	H & M
Rye, ground	2	87	84	..	92	64	H & M
Soybeans, ground	7	88	91	75	81	92	H & M
Velvet bean, seed and pod ground (velvet bean feed)	22	78	74	64	86	78	H & M
Wheat, ground	4	87	74	59	93	72	H & M
Wheat, durum	2	..	78	40	92	65	H & M
By-products of grains and seeds; miscellaneous concentrates							
Beet pulp, dried	3	75	52	83	83	..	H & M
Beet pulp, molasses	5	83	62	80	91	..	H & M
Blood, dried	2	..	84	..	..	..	H & M
Brewers' grains, dried	5	61	81	49	57	89	H & M
Buckwheat bran	..	49	47	39	56	56	H & M
Buckwheat middlings	5	74	87	32	86	83	H & M
Cocoa shells	2	58	11	51	73	100	H & M
Cocoanut meal or cake	3	82	90	23	87	100	H & M
Corn bran	6	71	60	71	80	80	H & M
Corn cob	3	54	19	60	52	50	H & M
Corn germ meal (corn oil cake meal)	5	76	73	75	78	96	H & M

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
CONCENTRATES—cont.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
By-products of grains and seeds; miscellaneous concentrates—cont.							
Corn gluten feed	19	86	85	76	88	85	H & M
Corn gluten meal	10	88	85	55	90	93	H & M
Cottonseed cake, cold-pressed	4	..	81	48	72	96	H & M
Cottonseed feed	34	56	58	45	61	90	H & M
Cottonseed hulls	13	41	6	47	34	79	L
Cottonseed meal, choice and prime	15	77	84	37	75	95	H & M
Distillers' grains, chiefly from corn	17	79	73	95	81	95	L
Distillers' grains, chiefly from rye	4	58	51	23	57	77	L
Fish meal	4	71	78	..	..	100	H & M
Flesh meal	5	..	93	..	..	98	M
Hominy feed	9	83	66	76	90	91	H & M
Linseed meal, new process	4	81	86	73	87	95	H & M
Linseed meal, old process	3	79	89	57	78	89	H & M
Malt sprouts	5	78	77	87	80	85	H & M
Molasses, cane, or blackstrap	26	78	32	..	90	..	H & M
Molasses feeds	8	68	61	50	79	100	H & M
Oat feed, low grade	15	48	75	42	46	78	H & M
Oat middlings	2	90	80	49	85	93	H & M
Palmnut cake	4	..	74	55	93	100	M
Pea hulls	4	..	71	94	90	73	M
Peanut cake, from hulled nuts	7	..	90	9	84	90	M
Peanut cake, many hulls	2	32	71	12	49	90	H & M
Rapeseed cake	7	..	81	8	76	79	M
Rye feed	3	82	80	..	88	90	H & M
Rice bran	6	61	65	25	79	77	H & M
Rice hulls	2	16	10	1	35	67	M
Rice polish	4	82	67	26	91	82	H & M
Sesame oil cake	8	..	92	73	71	94	M
Skim milk	3	98	94	..	98	98	H & M
Soybean oil meal	2	..	92	99	100	68	M
Sunflower seed cake	6	..	92	26	71	90	M
Vegetable ivory nut meal	8	88	18	86	94	49	L
Vinegar grains	4	61	64	58	56	83	L
Wheat bran, av. of all trials	20	65	78	31	72	68	H & M
Wheat bran, low grade	3	62	63	28	71	92	H & M
Wheat bran, spring	7	67	76	43	74	62	H & M
Wheat bran, winter	3	64	78	28	71	65	H & M
Wheat feed	4	73	77	36	76	87	H & M
Wheat middlings, flour	4	82	88	36	88	86	L
Wheat middlings, standard	6	..	77	30	78	88	L
Wheat screenings	4	63	72	..	73	88	H & M
DRIED ROUGHAGE							
Cured corn and sorghum forage							
Corn fodder, dent, mature	30	66	45	63	73	70	L
Corn fodder, dent, in milk	11	63	50	64	66	75	L
Corn fodder, southern dent, immature	4	57	27	59	61	76	L
Corn fodder, flint, mature	11	70	64	76	71	71	L
Corn fodder, flint, ears forming	3	70	70	72	71	67	L
Corn leaves	4	60	45	69	63	59	H & M
Corn husks	5	..	19	73	66	36	H & M
Corn fodder, sweet	6	67	64	74	68	74	H & M
Corn stover	35	57	37	66	59	62	H & M
Corn stover, tops and leaves	2	60	55	71	62	71	H & M

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cured corn and sorghum forage—cont.							
Kafir fodder	8	59	46	60	67	60	H & M
Kafir stover	5	56	34	67	60	75	H & M
Milo fodder	3	52	16	51	61	63	H & M
Sorghum fodder	20	58	38	61	63	65	H & M
Sorghum bagasse	1	61	14	64	65	46	H & M
Hay from the grasses, etc.							
Bermuda grass	9	54	52	52	51	42	H & M
Black grass	5	56	58	59	52	44	H & M
Bluegrass, Canada	2	62	43	70	62	37	H & M
Bluegrass, Kentucky	7	56	57	66	61	52	H & M
Brome grass	11	63	51	59	64	39	H & M
Brome grass, western	2	60	68	53	67	16	H & M
Buffalo grass	3	..	54	61	60	45	H & M
Bunch grass, black	4	..	20	54	47	37	H & M
Chess, or cheat	1	45	42	46	49	32	H & M
Crab grass, ripe	8	53	44	60	53	43	H & M
Fescue, meadow	2	61	52	67	59	54	H & M
Johnson grass	9	57	44	67	57	46	H & M
Millet, barnyard	4	59	61	64	56	47	H & M
Millet, Hungarian	2	65	60	68	67	64	H & M
Millet, pearl, or cat-tail	2	62	63	67	59	46	H & M
Mixed grasses, 8–10% protein	104	61	55	63	62	48	L
Mixed grasses, low in protein	34	..	50	55	59	49	M
Oat grass, tall	4	52	43	56	52	46	H & M
Orchard grass	3	58	60	61	56	55	H & M
Quack, or couch grass	3	62	57	61	67	56	H & M
Para grass	3	..	..	53	47	45	H & M
Prairie grass, western	16	..	..	58	53	42	H & M
Red top	3	60	62	61	63	53	H & M
Rush, Baltic	2	67	74	71	61	49	H & M
Salt grasses	5	54	45	59	53	35	H & M
Salt bushes	6	51	75	14	56	41	H & M
Sedges, western	2	62	62	70	65	42	H & M
Spear grasses	1	62	62	71	60	43	H & M
Sudan grass	6	60	45	64	64	55	H & M
Timothy, av. of all trials	58	55	48	50	62	50	L
Timothy, in bloom	8	59	57	57	63	48	L
Timothy, past bloom	17	52	43	46	59	51	L
Wheat grasses, miscellaneous	6	55	62	58	57	34	H & M
Wheat grass, western	10	64	55	69	63	41	H & M
Hay from the smaller cereals							
Barley	4	59	65	62	63	41	H & M
Oat	22	54	54	52	56	61	H & M
Hay from the legumes							
Alfalfa, av. of all trials	109	60	71	43	72	38	H & M
Alfalfa, first cutting	53	59	67	42	72	38	H & M
Alfalfa, second cutting	21	62	76	44	74	40	H & M
Alfalfa, third cutting	6	58	70	40	70	42	H & M
Alfalfa, budded to full bloom	74	60	70	43	72	39	H & M
Clover, alsike	15	56	62	48	64	43	H & M
Clover, bur	2	..	81	64	76	5	H & M
Clover, crimson	13	62	69	47	65	44	H & M
Clover, red, av. of all trials	25	59	59	54	66	57	H & M
Clover, red, in bloom	4	62	62	53	68	54	H & M

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
DRIED ROUGHAGE—cont.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the legumes—cont.							
Clover rowen	4	..	65	47	63	60	H & M
Clover, sweet, white	3	61	75	34	72	31	H & M
Clover, white	1	66	73	61	70	51	H & M
Cowpea	4	59	68	47	68	39	H & M
Lupine, wild	2	68	75	56	75	57	H & M
Peanut vine	5	60	72	52	72	80	H &M
Sanfoin	2	..	70	36	74	66	M
Serradella	2	..	75	50	63	65	M
Soybean	4	60	73	57	64	44	H & M
Vetch, common	5	65	67	57	72	64	H & M
Vetch, hairy	8	67	79	59	71	67	H & M
Hay from mixed grasses and legumes							
Clover and mixed grasses, western	8	68	55	72	70	70	H & M
Clover and timothy	13	55	47	51	60	45	H & M
Peas and oats	7	62	73	58	61	59	H & M
Vetch and oats	7	58	65	55	59	55	H & M
Vetch and wheat	6	66	74	65	68	64	H & M
Straw and chaff							
Barley straw	7	..	25	54	53	39	M
Flax shives	2	45	81	26	43	93	H & M
Horse bean straw	5	..	49	43	68	57	H & M
Oat straw	18	54	28	60	51	39	H & M
Oat chaff	2	..	38	45	49	48	M
Pea straw, field	2	59	58	56	67	48	H & M
Rice straw	6	..	22	59	46	23	H & M
Rye straw	9	..	23	55	39	36	M
Soybean straw	4	..	50	38	66	60	M
Wheat straw	10	..	23	50	37	31	M
Wheat chaff	3	..	26	39	33	43	M
FRESH GREEN ROUGHAGE							
Corn and the sorghums							
Corn fodder, dent, immature	14	68	66	65	71	86	L
Corn fodder, dent, in milk	17	70	62	64	77	76	L
Corn fodder, dent, mature	23	69	54	59	75	75	L
Corn fodder, flint, mature	4	69	52	75	71	66	L
Corn fodder, sweet, in milk	2	77	78	75	81	74	H & M
Corn fodder, sweet, roasting ears	12	..	62	60	77	75	H & M
Sorghum fodder, all trials	6	68	47	62	75	70	L
Fresh green grasses and cerals							
Barley	6	..	71	59	72	56	H & M
Bluegrass, native	2	53	64	45	60	50	H & M
Brome grass, western	2	60	68	53	67	16	H & M
Millet, barnyard	9	70	60	69	70	62	H & M
Millet, Hungarian	8	63	64	70	67	62	H & M
Mixed grasses, immature	2	..	70	66	75	62	M
Mixed grasses, late in season	4	..	56	62	61	46	M
Oat fodder	5	..	73	55	63	70	H & M
Orchard grass	3	..	60	60	55	54	M
Red top	3	..	61	61	62	50	M
Rye fodder	2	74	79	80	71	74	H & M
Timothy	3	63	48	56	66	53	H & M
Green legumes							
Alfalfa	2	61	74	42	72	38	H & M
Clover, crimson	3	..	77	56	74	66	H & M

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—cont.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green legumes—cont.							
Clover, red	2	66	67	53	78	65	H & M
Clover rowen	2	..	62	53	65	61	H & M
Cowpea	4	68	76	60	81	59	H & M
Lupine	2	68	75	56	76	57	L
Pea, field, Canada	8	63	81	49	74	54	H & M
Sanfoin	2	..	73	42	78	67	M
Soybean, all trials	23	64	77	45	75	53	H & M
Soybean, in bloom	2	..	77	47	71	50	H & M
Vetch, common	2	62	71	44	76	59	H & M
Vetch, hairy	14	71	83	64	77	72	H & M
Mixed legumes and grasses							
Peas and barley	4	..	75	52	68	59	H & M
Peas and oats	10	70	74	59	68	64	H & M
Vetch and oats	3	67	75	68	68	47	H & M
Vetch and wheat	5	69	74	68	73	57	H & M
Roots and tubers							
Beet, sugar	30	..	72	34	97	..	M
Carrot	7	94	84	100	100	100	L
Mangel	6	84	59	78	94	..	H & M
Potato	30	..	51	..	90	..	M
Rutabaga	2	87	80	74	95	84	H & M
Turnip	10	..	73	51	92	..	M
Miscellaneous green forages							
Cabbage	4	93	86	100	99	56	L
Cabbage waste, outer leaves	2	74	64	78	84	37	L
Cactus, prickly pear	4	65	50	47	81	68	H & M
Kale	4	68	81	59	76	66	H & M
Pumpkin	7	81	77	61	89	92	L
Rape	4	86	89	87	92	49	H & M
SILAGE							
Corn, dent, well-matured	27	66	51	65	71	82	L
Corn, dent, immature	17	64	53	68	66	71	L
Clover	10	54	51	49	61	62	H & M
Corn and soybean	8	69	63	62	77	83	H & M
Cowpea	4	60	57	52	73	63	H & M
Kafir, well matured	3	55	..	57	62	50	L
Millet, barnyard, and soybean	4	59	57	69	59	72	L
Oat and pea	2	65	75	61	67	75	H & M
Sorghum, well matured	3	57	..	58	64	56	L
Soybean	7	56	66	53	65	57	L
Sunflower	17	58	49	47	67	75	H & M
Vetch	2	63	56	63	67	77	H & M

TABLE II. Average digestibility of American feeding stuffs—*continued.*

B. Experiments with Horses

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn	2	74	58	..	83	48	H & M
Corn meal	2	88	76	..	96	73	H & M
Oats	34	..	80	29	75	71	M
Timothy hay	2	44	21	43	47	47	H & M
Meadow hay, excellent	4	..	63	48	65	22	M
Meadow hay, good	14	..	58	39	58	18	M
Meadow hay, poor	12	..	55	38	52	29	M
Alfalfa hay	6	..	73	46	70	14	M
Clover hay, red	5	..	56	37	63	29	M

C. Experiments with Calves

Whole milk	13	..	94	..	98*	97	H & M
Pasteurized whole milk	9	..	93	..	98*	96	H & M
Cooked whole milk	3	..	87	..	98*	95	H & M
Skim milk	3	..	95	..	98*	..	H & M

D. Experiments with Swine

Shelled corn	33	87	75	44	92	64	H & M
Ground corn	47	87	76	46	93	64	H & M
Corn-and-cob meal	1	76	76	28	84	82	H & M
Wheat	2	..	80	60	83	70	M
Red dog flour	2	87	88	..	..	36	H & M
Wheat middlings (shorts)	9	82	83	30	86	83	H & M
Wheat bran	2	66	75	39	66	72	M
Barley	29	..	77	12	89	44	M
Rye	4	..	84	10	94	41	M
Sorghum seed	9	..	60	20	83	72	M
Broom-corn millet seed	1	73	68	33	92	59	H & M
Rice	2	..	86	..	100	70	M
Pea meal	11	..	90	70	96	49	M
Linseed meal, old process	9	78	85	16	82	70	H & M
Soybean meal	5	..	84	30	100	84	H & M
Skim milk	5	..	100	..	100	100	H & M
Dried blood	1	72	72	..	92	..	M
Tankage	5	..	71	..	100	100	H & M
Pork cracklings	20	100	94	..	..	100	H & M
Potato	4	97	84	..	98	..	L

*Assumed.

Table III. Average Digestible Nutrients and Fertilizing Constituents in American Feeding Stuffs

The data for the digestible nutrients in this table are derived by combining the data in the two preceding tables, according to the method described in Article **69** of the text. Where no digestion coefficients are available for any feed, the digestion coefficients for a similar feed have been used and that fact indicated by an asterisk. The total digestible nutrients given in the fifth column is the sum of the digestible crude protein, the digestible carbohydrates, and the digestible fat × 2.25. (**69-70**) For convenience in computing rations, the sixth column, showing the nutritive ratio of each feeding stuff, has been added to the table.

The figures for dry matter, digestible crude protein, and total digestible nutrients are printed in black-face type, since these values are the only ones needed in computing rations according to the Morrison Standards given in Appendix Table V.

The fertilizing constituents given are mostly from an exhaustive compilation by the authors of the analyses reported by the State Experiment Stations and the United States Department of Agriculture.

This table is fully protected by copyright.

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Grains and seeds									
Barley, common	**90.7**	**9.0**	66.8	1.6	**79.4**	7.8	18.4	8.5	**7.4**
Barley, hulless*	**90.6**	**8.4**	67.5	2.0	**80.4**	8.6	17.3	....	....
Bean, Adzuki*	**86.0**	**17.4**	54.3	0.4	**72.6**	3.2	33.6	....	....
Bean, navy*	**86.6**	**18.8**	51.3	0.8	**71.9**	2.8	36.3	7.8	**13.7**
Broom-corn seed*	**88.2**	**8.3**	62.9	2.6	**77.0**	8.3	16.3	....	....
Buckwheat	**87.9**	**8.1**	49.7	2.5	**63.4**	6.8	17.3	10.0	**7.0**
Carob bean and pod*	**86.7**	**5.3**	56.6	1.9	**66.2**	11.5	10.9	....	....
Chess, or cheat, seed*	**92.3**	**6.2**	60.6	1.5	**70.2**	10.3	16.8	....	....
Corn, dent, well cured	**89.5**	**7.5**	67.8	4.6	**85.7**	10.4	16.2	6.9	4.0
Corn, dent, grade No. 1	**88.0**	**7.4**	66.6	4.5	**84.2**	10.4	15.9	6.8	3.9
Corn, dent, grade No. 2	**85.2**	**7.1**	64.6	4.4	**81.7**	10.4	15.4	6.6	3.8
Corn, dent, grade No. 3	**83.5**	**7.0**	63.3	4.3	**80.0**	10.4	15.1	6.4	3.7
Corn, dent, grade No. 4	**81.5**	**6.8**	61.8	4.2	**78.1**	10.4	14.8	6.3	3.6
Corn, dent, grade No. 5	**79.5**	**6.7**	60.2	4.1	**76.1**	10.4	14.4	6.1	3.6
Corn, flint	**87.8**	**7.7**	66.1	4.6	**84.2**	9.9	16.6	6.8	3.9
Corn, pop*	**90.6**	**9.0**	66.7	4.8	**86.5**	8.6	19.4	....	....
Corn, soft (immature)	**69.4**	**5.5**	53.3	3.5	**66.7**	11.1	11.8	5.4	3.1
Corn, sweet, (mature)*	**90.7**	**8.5**	64.5	7.3	**89.4**	9.5	18.4	....	....
Corn-and-cob meal	**89.6**	**6.1**	63.7	3.7	**78.1**	11.8	13.8	5.8	6.3
Corn and oat feed*	**88.6**	**7.3**	60.6	3.4	**75.6**	9.4	15.4	7.5	4.8
Corn and oat feed, low grade*	**90.5**	**6.0**	52.4	3.1	**65.4**	9.9	14.2	5.7	5.1
Cotton seed	**90.6**	**13.3**	29.6	16.5	**80.0**	5.0	31.2	15.0	**15.0**
Cowpea seed	**88.4**	**19.4**	54.5	1.1	**76.4**	2.9	37.8	10.1	**14.9**
Darso grain*	**88.3**	**9.2**	64.5	2.7	**79.8**	7.7	18.2	....	....
Durra grain*	**90.1**	**8.2**	67.9	2.7	**82.2**	9.0	16.2	....	....
Emmer (spelt)	**91.3**	**9.5**	63.2	1.7	**76.5**	7.1	19.0	7.6	**5.7**
Emmer, without hulls*	**89.5**	**11.9**	62.3	2.2	**79.2**	5.7	23.8	....	....
Feterita grain*	**88.9**	**10.1**	65.4	2.4	**80.9**	7.0	20.0	....	....
Feterita head chops*	**88.8**	**7.0**	56.8	1.8	**67.8**	8.7	17.8	....	....
Flax seed	**90.8**	**20.6**	17.0	29.0	**102.8**	4.0	36.2	15.0	**9.5**
Frijole*	**90.4**	**20.4**	53.8	0.6	**75.6**	2.7	39.4	....	....
Horse bean	**87.4**	**22.8**	49.1	0.7	**73.5**	2.2	41.9	12.4	**13.4**
Jack bean*	**88.5**	**20.7**	50.9	2.2	**76.6**	2.7	38.1	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Grains and seeds—cont.									
Kafir grain	88.2	9.0	65.8	2.3	80.0	7.9	17.8	5.7	3.1
Kafir-head chops	87.5	6.1	56.6	2.0	66.7	9.9	15.5	....	....
Kaoliang grain*	90.1	8.5	67.0	3.3	82.9	8.8	16.8	....	....
Lamb's quarter seed*	90.2	10.2	40.6	6.9	66.3	5.5	22.6	....	....
Millet seed, barnyard*	89.8	7.6	57.0	3.4	72.2	8.5	17.1	....	....
Millet seed, foxtail	89.2	8.6	60.6	3.0	76.0	7.8	19.4	4.6	3.7
Millet seed, hog, or broom-corn	90.9	8.4	63.7	2.4	77.5	8.2	18.9	7.2	5.2
Millet seed, pearl	92.0	8.3	64.7	4.9	84.0	9.1	18.7	....	....
Milo grain*	89.3	8.7	66.2	2.2	79.9	8.2	17.1	7.8	4.3
Milo-head chops*	89.7	6.3	58.1	1.9	68.7	9.9	16.0	....	....
Oats	90.8	9.7	52.1	3.8	70.4	6.3	19.8	8.1	5.6
Oats, light weight*	91.3	9.6	49.5	4.1	68.3	6.1	19.7	8.2	5.7
Oats, ground, low grade	89.8	6.9	37.0	3.2	51.1	6.4	15.4	5.9	6.3
Peanut, with shell*	94.1	17.9	8.2	32.6	99.4	4.6	40.3	7.6	6.4
Pea, field	90.8	19.0	55.8	0.6	76.2	3.0	36.6	8.4	10.1
Pea, garden	88.2	21.2	51.5	0.9	74.7	2.5	41.0	....	....
Pigeon-grass seed*	89.3	8.5	45.4	4.3	63.6	6.5	23.0	....	....
Pigweed seed*	93.7	10.8	43.8	6.0	68.1	5.3	24.0	....	....
Rice, rough*	90.4	4.7	64.6	1.7	73.1	14.6	12.2	4.9	2.6
Rye	90.6	9.9	68.4	1.2	81.0	7.2	18.9	7.3	5.7
*Sesbania macrocarpa**	90.8	27.6	42.4	3.6	78.1	1.8	50.7	....	....
Shallu grain*	90.3	10.1	66.3	2.6	82.2	7.1	20.0	....	....
Sorghum grain*	87.3	7.5	66.2	2.6	79.5	9.6	14.7	8.2	3.3
Soybean seed	90.1	33.2	24.7	16.1	94.1	1.8	58.4	13.7	24.7
Sunflower seed, with hulls*	93.1	13.5	38.1	20.3	97.3	6.2	25.8	12.2	5.6
Sunflower seed, without hulls*	95.5	23.3	17.0	33.9	116.6	4.0	44.3	....	....
Tepary*	90.5	18.4	56.6	0.8	76.8	3.2	35.5	....	....
Velvet bean, seed*	88.3	18.1	50.8	5.3	80.8	3.5	33.3	....	....
Velvet bean, seed and pod*	90.3	13.6	51.6	3.4	72.8	4.4	29.4	6.9	15.9
Wheat, all analyses	89.8	9.2	67.5	1.5	80.1	7.7	19.8	8.6	5.3
Wheat, Atlantic states	88.8	8.7	67.5	1.4	79.4	8.1	18.7	8.5	5.2
Wheat, Minn., N.D., S. D., Nebr., Kan.	89.6	10.0	66.3	1.5	79.7	7.0	21.6	8.6	5.2
Wheat, Miss. Valley, except above states	89.5	9.1	67.5	1.4	79.8	7.8	19.7	8.6	5.2
Wheat, Rocky Mountain states	91.5	9.8	68.1	1.6	81.5	7.3	21.3	8.7	5.4
Wheat, Pacific states	89.1	7.3	69.1	1.4	79.6	9.9	15.8	8.5	5.2
Wheat, spring	89.9	9.2	67.2	1.6	80.0	7.7	20.0	8.6	5.3
Wheat, durum	89.6	11.0	64.2	1.6	78.8	6.2	22.6	8.6	5.2
Wheat, Polish*	90.5	15.0	60.9	1.2	78.6	4.2	32.5	8.6	5.3
Wheat, winter	89.1	8.7	67.8	1.4	79.7	8.2	18.7	8.5	5.2
By-products of grains and seeds; miscellaneous concentrates									
Acorn, kernel and shell*	72.1	2.3	36.2	3.8	47.1	19.5	5.4	....	....
Acorn, kernel*	65.6	2.9	27.3	4.7	40.8	13.1	6.7	....	....
Bakery refuse*	91.7	8.3	60.8	7.0	84.9	9.2	17.9	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—cont. *By-products of grains and seeds; miscellaneous concentrates*—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Barley bran, nearly all hulls*	91.9	4.4	34.9	1.0	41.6	8.5	9.4	....	....
Barley feed, low grade*	92.2	8.7	38.8	2.1	52.2	5.0	18.2	....	....
Barley screenings*	88.6	8.3	47.7	2.5	61.6	6.4	18.4	....	....
Barley shorts, or barley feed, high grade*	89.8	10.0	46.3	2.4	61.7	5.2	20.5	12.8	8.9
Beet pulp, dried	91.8	4.6	65.2	0.8	71.6	14.6	14.2	2.4	3.8
Beet pulp, molasses-	92.4	5.9	68.0	0.6	75.3	11.8	15.2	1.5	18.1
Beet pulp, wet	9.3	0.5	6.5	0.2	7.4	13.8	1.4	0.4	0.7
Bread*	66.2	5.8	51.9	0.5	58.8	9.1	12.6	2.0	1.2
Brewers' grains, dried	92.5	21.5	30.5	6.1	65.7	2.1	42.4	9.9	0.9
Brewers' grains, wet*	24.1	4.6	8.7	1.5	16.7	2.6	9.1	2.4	0.3
Buckwheat feed, good grade*	88.2	9.1	30.2	2.9	45.8	4.0	30.9	11.0	7.9
Buckwheat feed, low grade*	88.1	3.7	24.0	2.1	32.4	7.8	21.3	8.4	8.2
Buckwheat flour*	87.2	5.9	58.0	1.5	67.3	10.4	12.6	4.4	1.9
Buckwheat hulls*	89.7	0.4	23.6	0.4	25.6	63.0	7.0	5.7	8.6
Buckwheat middlings	88.0	24.6	38.3	6.1	76.6	2.1	45.3	23.4	11.8
Cassava, dried*	94.4	1.4	77.4	0.2	79.2	55.6	4.5	....	....
Cassava starch refuse*	88.0	0.5	56.4	0.6	58.3	115.6	1.3	0.6	2.8
Cocoa shells	95.1	1.7	44.8	3.0	53.3	30.4	24.6	13.4	26.0
Cocoanut meal or cake, new process*	90.0	19.9	44.2	3.0	70.8	2.6	35.4	....	....
Cocoanut meal or cake, old process	89.8	18.6	41.3	8.4	78.8	3.2	33.1	12.4	23.6
Cocoanut meal or cake, old process, high in fat	92.3	18.4	37.6	17.1	94.5	4.1	32.6	7.8	24.2
Corn bran	90.0	5.8	56.9	4.6	73.1	11.6	15.5	6.2	5.4
Corn cob	90.0	0.4	47.3	0.2	48.1	119.2	3.2	0.7	6.6
Corn germ meal	91.1	16.5	42.6	10.4	82.5	4.0	36.2	13.2	2.5
Corn gluten feed	91.3	21.6	51.9	3.2	80.7	2.7	40.6	6.2	2.3
Corn gluten meal	90.6	37.7	36.7	2.7	80.5	1.1	71.0	5.5	1.2
Corn, oat, and barley feed*	90.3	9.1	59.9	4.0	78.0	7.6	18.2	....	....
Cottonseed cake, cold-pressed	92.1	21.1	33.2	7.4	70.9	2.4	41.8	....	....
Cottonseed meal, choice	92.5	37.0	21.8	8.6	78.2	1.1	70.6	26.7	18.1
Cottonseed meal, prime	92.2	33.4	24.3	7.9	75.5	1.3	63.7	26.6	18.0
Cottonseed meal, good*	92.1	31.6	25.6	7.8	74.8	1.4	60.2	26.6	18.0
Cottonseed feed	91.7	14.2	30.7	5.7	57.7	3.1	39.2	14.7	14.7
Cottonseed-hull bran*	91.6	0.2	33.3	0.9	35.5	176.5	5.4	....	....
Cottonseed hulls	90.3	0.3	33.3	1.5	37.0	122.3	7.4	3.6	12.8
Distillers' grains, dried, from corn	93.4	22.4	40.4	11.6	88.9	3.0	49.1	6.8	1.7
Distillers' grains, dried, from rye	92.8	11.8	29.4	6.0	54.7	3.6	37.0	8.3	2.4
Distillers' grains, wet*	22.6	3.3	13.3	1.5	20.0	5.1	7.2	1.6	0.4
Distillery slop, strained*	4.1	1.0	1.4	0.7	4.0	3.0	2.2	....	....
Distillery slop, whole*	6.2	1.4	2.8	0.6	5.6	3.0	3.0	1.3	0.7

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES — cont. *By-products of grains and seeds; miscellaneous concentrates* — cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Flax feed*	90.6	12.0	34.2	12.5	74.3	5.2	26.6	....	....
Flax screenings*	91.4	11.1	35.1	10.4	69.6	5.3	24.6	5.3	12.6
Hominy feed	89.9	7.0	61.2	7.3	84.6	11.1	17.0	12.4	9.5
Hominy, pearled*	89.4	5.8	72.1	3.1	84.9	13.6	12.5	2.3	1.6
Linseed meal, new process	90.4	31.7	37.9	2.8	75.9	1.4	59.0	17.7	13.0
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1.6	54.2	17.0	12.7
Malt*	94.2	15.8	62.7	3.2	85.7	4.4	28.8	9.5	4.5
Malt sprouts	92.4	20.3	47.4	1.3	70.6	2.5	42.2	16.5	18.3
Molasses, beet*	78.0	2.9	55.8	....	58.7	19.2	14.4	0.5	58.8
Molasses, cane, or blackstrap	74.3	1.0	58.5	....	59.5	58.5	5.1	2.4	31.6
Molasses feeds, below 10% fiber	88.4	8.2	47.2	5.0	66.6	7.1	21.4	8.4	20.6
Molasses feeds, 10–15% fiber	88.3	7.4	47.7	4.2	64.5	7.7	19.5	8.4	20.6
Molasses feeds, over 15% fiber	90.7	8.4	45.5	2.8	60.2	6.2	21.9	....	....
Molasses-alfalfa feeds	86.5	8.5	41.0	0.5	50.6	5.0	19.2	....	....
Molassine meal	83.4	5.4	50.3	0.8	57.5	9.6	14.1	....	....
Mustard feed or bran	94.3	22.8	28.7	10.2	74.5	2.3	50.7	....	....
Oat bran*	93.6	8.8	36.1	3.9	53.7	5.1	19.5	....	....
Oat dust*	93.4	9.1	34.9	4.3	53.7	4.9	20.2	....	....
Oat feed, low grade (chiefly hulls)	93.5	4.1	35.6	1.6	43.3	9.5	8.8	....	....
Oat hulls	93.2	3.0	36.3	1.3	42.2	13.0	6.4	2.1	5.8
Oat kernel (without hull)*	93.1	11.4	57.7	7.5	86.0	6.5	22.9	....	....
Oat meal (rolled oats)*	92.1	12.8	56.9	6.0	83.2	5.5	25.6	....	....
Oat middlings	92.7	13.0	55.2	6.3	82.4	5.3	26.1	12.8	6.9
Oat shorts	93.9	12.9	54.3	5.5	79.6	5.2	25.8	....	....
Palmnut cake	89.6	12.4	45.8	9.5	79.6	5.4	26.9	11.0	5.0
Pea bran*	90.1	8.7	65.2	0.8	75.7	7.7	19.5	3.1	10.3
Pea hulls	92.8	4.9	74.7	0.9	81.6	1.6	11.0	....	....
Pea meal	89.1	19.8	53.6	0.8	75.2	2.8	38.1	9.2	10.0
Peanut kernel, without shells*	94.7	27.4	10.0	42.9	133.9	3.9	48.8	10.2	6.5
Peanut oil feed, from unshelled nuts	92.5	24.2	13.6	7.7	55.1	1.3	54.6	....	....
Peanut oil meal or cake, from shelled nuts	93.4	40.3	22.5	9.2	83.5	1.1	71.7	12.1	10.5
Peanut shells, commercial	90.9	0.4	33.0	2.1	38.1	94.2	11.7	1.4	7.4
Potato flakes, dried	87.9	3.6	67.2	0.2	71.2	18.8	11.4	....	....
Potato flour	89.4	1.4	73.9	0.4	76.2	53.4	4.3	....	....
Red dog flour*	88.9	14.8	56.5	3.5	79.2	4.4	26.9	20.0	7.6
Rice, polished*	87.7	4.6	72.8	0.4	78.3	16.0	11.8	1.7	0.6
Rice bran, high grade	89.9	7.9	38.1	8.8	65.8	7.3	19.4	22.2	12.0

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES — cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
By-products of grains and seeds; miscellaneous concentrates—cont.									
Rice bran, low grade	90.5	7.1	37.7	7.5	61.7	7.7	17.4	22.6	12.2
Rice hulls	90.7	0.3	12.3	0.7	14.2	46.3	5.3	0.9	2.2
Rice meal	90.5	7.3	48.1	10.6	79.2	9.8	18.9	....	....
Rice polish	90.0	8.0	57.2	7.5	82.1	9.3	19.0	30.8	11.7
Rye bran*	88.6	12.2	56.6	2.8	75.1	5.2	24.5	15.4	9.6
Rye feed (middlings and bran)	88.5	12.2	55.8	2.9	74.5	5.1	24.5	5.6	4.6
Rye flour*	88.2	6.6	72.0	0.7	80.2	11.2	12.6	....	....
Rye middlings*	88.6	12.6	55.5	3.1	75.1	5.0	25.1	5.6	4.9
Soybean oil meal	89.5	39.7	34.7	4.5	84.5	1.1	69.1	....	....
Starch feed, dry	90.7	11.2	55.0	6.6	81.0	6.2	24.6	2.2	0.7
Sunflower seed cake	90.0	32.0	18.3	16.5	87.4	1.7	55.7	21.6	11.7
Vegetable ivory nut meal	90.0	0.8	77.8	0.5	79.7	98.6	7.0	....	....
Wheat bran, all analyses	89.9	12.5	41.6	3.0	60.9	3.9	25.6	29.5	16.2
Wheat bran, spring	89.6	11.9	43.3	3.0	62.0	4.2	25.1	29.4	16.2
Wheat bran, winter	89.4	12.2	40.9	2.9	59.6	3.9	25.1	29.3	16.1
Wheat bran, low grade*	90.0	7.5	41.4	3.3	56.3	6.5	19.0	29.5	16.2
Wheat feed (middlings and bran)	89.9	12.9	45.1	4.0	67.0	4.2	26.9	21.9	8.8
Wheat flour, graham*	88.0	12.1	61.2	1.8	77.3	5.4	21.9	6.4	4.0
Wheat flour, patent*	87.7	8.1	69.6	0.9	79.7	8.8	17.4	2.0	1.0
Wheat middlings, flour	89.3	15.7	52.8	4.3	78.2	4.0	28.5	....	....
Wheat middlings, standard (shorts)	89.5	13.4	46.2	4.3	69.3	4.2	27.7	21.1	11.8
Wheat screenings	89.8	9.6	47.3	3.6	65.0	5.8	21.3	7.4	7.6
Yeast and vinegar grains	94.0	12.6	36.9	5.6	62.1	3.9	31.5	....	....
Milk and its products									
Cow's milk	13.6	3.3	4.8	3.6	16.2	3.9	5.6	1.9	1.7
Cow's milk, colostrum	25.5	16.5	2.6	3.5	27.0	0.6	28.2	6.6	1.1
Buttermilk*	9.4	3.4	4.9	0.1	8.4	1.5	5.8	1.7	1.6
Buttermilk, dried	88.3	29.3	41.0	6.2	84.2	1.9	49.9	....	....
Buttermilk, semi-solid	35.0	12.6	16.7	3.5	36.2	1.9	21.4	....	....
Skim milk, centrifugal	9.9	3.6	5.1	0.2	9.1	1.5	6.1	2.2	1.7
Skim milk, gravity	9.6	3.1	4.6	0.9	9.7	2.1	5.3	2.2	1.7
Skim milk, dried*	96.0	35.1	48.3	1.3	86.3	1.5	59.7	....	....
Whey	6.6	0.8	4.7	0.3	6.2	6.8	1.6	1.2	2.6
Slaughter house by-products									
Dried blood	90.3	69.1	....	0.9	71.1	0.03	131.5	4.9	1.2
Fish meal	89.5	40.1	....	8.3	58.8	0.5	82.2	139.5	3.0
Fish-glue waste*	86.0	30.5	....	7.9	48.3	0.6	62.6	....	....
Fresh bone*	69.6	18.3	....	24.5	73.4	3.0	31.5	....	....
Meat-and-bone meal, 30–40% ash*	94.0	37.0	....	11.0	61.8	0.7	63.7	....	....
Meat-and-bone meal, over 40% ash*	93.4	30.9	....	9.8	53.0	0.7	53.1	....	....
Pork cracklings*	95.0	52.4	....	32.6	125.8	1.4	90.2	6.1	....
Poultry bone*	92.7	22.6	....	3.0	29.4	0.3	38.9	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES — cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Slaughter house by-products—cont.									
Tankage, guaranteed 60% protein*	92.1	56.2	....	7.2	71.4	0.3	96.6	55.8	5.5
Tankage, guaranteed 50 to 60% protein*	91.0	48.1	....	10.2	71.0	0.5	76.8	....	....
Tankage, guaranteed 40 to 50% protein*	91.5	42.8	....	15.6	77.9	0.8	73.6	101.5	....
Tankage, below 40% protein*	90.9	34.3	....	14.1	66.0	0.9	59.0	135.7	....
DRIED ROUGHAGE									
Cured corn and sorghum forage, etc.									
Corn fodder (ears, if any, remaining), very dry, from barn or in arid districts	91.0	3.5	51.7	1.5	58.6	15.7	12.5	3.7	9.9
Corn fodder, medium in water	81.7	3.0	47.3	1.5	53.7	16.9	10.7	3.3	8.9
Corn fodder, high in water	60.7	2.2	35.5	1.0	39.9	17.1	7.7	2.5	6.6
Corn fodder, sweet corn	87.7	5.9	47.6	1.3	56.4	8.6	14.7	4.0	11.8
Corn leaves	76.6	3.2	40.1	1.1	45.8	13.3	11.4	....	....
Corn husks	75.3	0.6	47.3	0.3	48.6	80.0	4.6	2.3	10.2
Corn stover (ears removed) very dry	90.6	2.2	47.8	1.0	52.2	22.7	9.4	4.5	12.9
Corn stover, medium in water	81.0	2.1	42.4	0.7	46.1	21.0	9.1	4.0	11.5
Corn stover, high in water	59.0	1.4	31.1	0.6	33.9	23.2	6.2	2.9	8.3
Corn tops	82.1	3.1	45.5	1.1	51.1	15.5	9.0	....	....
Broom-corn fodder*	90.6	0.6	44.6	1.1	47.7	78.5	6.2	....	....
Durra fodder*	89.9	1.0	43.6	1.8	48.6	47.6	10.2	....	....
Japanese cane fodder*	93.2	0.5	55.0	1.2	58.2	115.4	2.2	....	....
Kafir fodder, dry	91.0	4.1	45.0	1.7	52.9	11.9	14.2	....	....
Kafir fodder, high in water	71.7	3.0	38.2	1.6	44.8	13.9	10.4	....	....
Kafir stover, dry	83.7	1.7	43.1	1.3	47.7	27.1	8.2	....	....
Kafir stover, high in water	72.7	1.3	37.8	1.0	41.3	30.8	6.1	....	....
Milo fodder, dry	88.9	1.9	36.3	2.8	44.5	22.4	19.2	....	....
Milo fodder, high in water	60.9	0.6	29.8	1.4	33.6	55.0	5.9	....	....
Milo stover, high in water*	64.5	0.4	31.3	0.5	32.8	81.0	3.7	....	....
Sorghum fodder, dry	90.3	2.8	44.8	2.0	52.1	17.6	11.8	....	....
Sorghum fodder, high in water	62.6	1.5	32.9	1.8	38.4	24.6	6.2	....	....
Sorghum bagasse, dried	88.7	0.5	52.3	0.6	54.2	107.4	5.4	....	....
Sugar-cane bagasse*	89.8	0.5	47.6	3.3	55.5	110.0	5.3	....	....
Hay from the grasses, etc.									
Bent grass, Canada, or blue joint*	93.3	4.6	44.6	1.3	52.1	10.3	12.2	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—cont. *Hay from the grasses, etc.*—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Bermuda grass	90.3	3.7	37.9	0.8	43.4	10.7	11.4	4.0	20.0
Black grass	89.7	4.4	39.4	1.1	46.3	9.5	12.0	2.0	18.8
Bluegrass, Canada	89.3	2.8	48.5	0.9	53.3	18.0	10.6	4.5	23.3
Bluegrass, Kentucky, all analyses	86.8	4.7	43.5	1.5	51.6	10.0	13.3	5.4	21.0
Bluegrass, Kentucky, in milk	87.6	4.8	44.1	1.5	52.3	9.9	13.6	....	....
Bluegrass, Kentucky, ripe	88.0	4.0	44.2	1.8	52.3	12.0	11.3	....	....
Bluegrass, native western*	91.9	6.4	44.0	1.6	54.0	7.4	17.9	....	....
Brome grass, smooth	91.5	5.0	44.2	0.9	51.2	9.2	15.8	4.2	21.5
Bluestem grasses*	93.1	2.4	44.6	0.8	48.8	19.3	7.8	....	....
Buffalo grass	93.0	3.8	43.9	0.8	49.5	12.0	11.2	....	....
Bunch grasses, miscellaneous	93.0	1.2	37.9	0.7	40.7	32.9	9.6	....	....
Carpet grass*	92.1	3.1	44.6	1.0	49.9	15.1	11.2	....	....
Chess, or cheat	91.6	3.0	35.5	0.7	40.1	12.4	11.5	6.6	17.8
Crab grass	90.5	3.5	40.0	1.0	45.7	12.1	12.8	9.0	30.9
Crow-foot grass*	90.5	3.8	40.0	0.9	45.8	11.1	13.8	....	....
Fescue, meadow	88.3	3.5	45.2	1.1	51.2	13.6	10.9	4.6	17.2
Fescues, native*	95.1	4.6	48.9	1.1	56.0	11.2	14.2	....	....
Fowl meadow grass*	88.9	6.1	43.0	1.4	52.3	7.6	15.7	....	....
Foxtails, miscellaneous*	93.2	5.6	48.0	1.7	57.4	9.2	14.9	....	....
Gama grass*	88.2	3.4	40.5	0.8	45.7	12.4	10.7	....	....
Grama grasses*	93.4	3.2	41.9	0.7	46.7	13.6	10.2	....	....
Hair grasses, miscellaneous*	93.4	4.2	41.9	0.9	48.1	10.5	13.3	4.7	17.3
Johnson grass	89.9	2.9	45.0	1.0	50.1	16.3	10.6	4 2	11.3
Millet, barnyard	86.5	5.1	40.5	0.8	47.4	8.3	13.3	5.5	25.3
Millet, common, or Hungarian	85.7	5.0	46.0	1.8	55.0	10.0	13.3	3.6	21.5
Millet, German*	91.3	4.8	49.7	1.7	58.3	11.1	12.8	3.5	14.4
Millet, hog, or broomcorn*	90.7	5.3	49.5	1.6	58.4	10.0	14.1	4.4	21.1
Millet, pearl, or cat-tail	87.2	4.2	43.8	0.8	49.8	10.9	10.7	....	....
Millet, wild, or Indian*	93.3	6.4	49.5	1.5	59.3	8.3	17.0	....	....
Mixed grasses	87.2	4.3	44.3	1.2	51.3	10.9	12.2	3.8	16.4
Mixed grasses, rowen	86.4	7.0	39.9	1.6	50.5	6.2	19.7	3.3	16.6
Natal grass*	90.2	3.7	37.9	0.8	43.4	10.7	11.8	....	....
Needle grasses*	94.7	3.9	43.9	0.8	49.6	11.7	12.5	....	....
Nerved manna grass*	93.8	4.0	41.4	0.8	47.2	10.8	12.8	....	....
Oat grass, tall, or meadow oat grass	88.2	3.4	38.4	1.2	44.5	12.1	12.8	3.1	16.4
Old witch grass*	92.9	6.5	41.1	1.0	49.8	6.7	17.0	....	....
Orchard grass	88.4	4.7	41.1	1.6	49.4	9.5	12.6	4.0	19.4
Para grass	90.2	2.3	38.7	0.4	41.9	17.2	7.4	....	....
Panic grasses*	92.1	4.7	46.1	1.2	53.5	10.4	13.3	2.6	6.3
Prairie hay, western	93.5	4.0	41.4	1.1	47.9	11.0	12.8	....	....
Quack grass	94.1	4.2	49.7	1.1	56.4	12.4	11.7	....	....
Rescue grass*	90.2	5.0	43.0	1.2	50.7	9.1	15.7	5.5	15.6

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the grasses, etc.—cont.									
Red top, all analyses	90.2	4.6	45.9	1.2	53.2	10.6	11.8	4.4	18.8
Red top, in bloom	92.0	4.5	46.4	1.1	53.4	10.9	11.5	....	....
Reed bent grass*	94.1	6.1	44.4	1.3	53.4	7.8	16.3	....	....
Reed canary grass*	90.4	4.5	44.6	1.4	52.3	10.6	12.6	5.2	18.9
Reed grasses, miscellaneous western*	93.0	3.1	42.8	0.9	47.9	14.5	9.9	....	....
Reed meadow grass, or manna*	93.3	4.6	39.8	0.8	46.2	9.0	14.9	....	....
Rhode Island bent grass*	88.5	4.1	45.0	1.6	52.7	11.9	10.6	4.1	17.0
Rye grass, Italian*	88.6	3.9	40.7	1.0	46.8	11.0	13.0	....	....
Rye grass, perennial*	88.0	4.4	39.0	1.6	47.0	9.7	14.7	....	....
Rushes, western	94.3	7.5	48.5	0.9	58.0	6.7	16.3	....	....
Salt grasses, miscellaneous	94.7	3.6	40.0	0.7	45.2	11.6	13.0	....	....
Sedges, western	94.8	6.9	49.8	1.0	58.9	7.5	17.9	....	....
Sedges, eastern*	90.7	2.7	41.8	0.6	45.9	16.0	9.8	2.0	9.3
Spear grasses	94.5	4.7	50.7	0.9	57.4	11.2	12.2	....	....
Sudan grass	88.4	3.7	45.7	0.9	51.4	12.9	13.1	....	....
Swamp grasses*	90.2	3.5	40.1	0.8	45.4	12.0	12.3	....	....
Sweet vernal grass*	90.7	7.1	39.9	2.3	52.2	6.4	19.8	5.9	18.5
Teosinte*	89.4	5.6	40.2	0.9	47.8	7.5	14.6	7.5	42.6
Timothy, all analyses	88.4	3.0	42.8	1.2	48.5	15.2	9.9	3.1	13.6
Timothy, before bloom	92.8	4.7	42.0	1.6	50.3	9.7	15.7	....	....
Timothy, early to full bloom	87.2	3.6	44.7	1.2	51.0	13.2	10.1	....	....
Timothy, late bloom to early seed	85.1	2.4	39.0	1.4	44.6	17.6	8.8	....	....
Timothy, nearly ripe	87.5	2.2	40.7	1.1	45.4	19.6	8.3	....	....
Timothy rowen*	84.9	8.2	35.8	2.1	48.7	4.9	23.0	....	....
Wheat grass, common*	92.7	4.0	44.0	0.8	49.8	11.4	10.4	....	....
Wheat grasses, miscellaneous	93.6	4.4	44.7	0.8	50.9	10.6	11.4	....	....
Wheat grass, western	94.1	4.2	50.5	0.9	56.7	12.5	12.3	....	....
Wild barley, or foxtail*	92.5	4.0	48.4	1.1	54.9	12.7	11.2	....	....
Wild oat*	92.1	3.8	42.8	1.4	49.8	12.1	12.8	....	....
Wild rye*	89.2	4.0	47.3	1.1	53.8	12.4	11.4	6.3	19.5
Hay from the smaller cereals									
Barley hay, common	92.6	4.6	48.2	0.9	54.8	10.9	11.2	....	....
Barley hay, bald	91.3	4.8	47.0	0.9	53.8	10.2	11.8	....	....
Emmer hay*	92.3	6.5	44.3	0.9	52.8	7.1	16.0	....	....
Oat hay	88.0	4.5	38.1	1.7	46.4	9.3	13.4	8.0	32.7
Rye hay, all analyses*	91.9	2.9	41.1	1.1	46.5	15.0	10.7	5.0	17.0
Rye hay, heading out to in bloom*	91.8	6.4	46.0	1.1	54.9	7.6	15.7	....	....
Wheat hay*	91.9	4.0	48.5	0.8	54.3	12.6	9.9	....	....
Hay from the legumes									
Alfalfa, all analyses	91.4	10.6	39.0	0.9	51.6	3.9	23.8	5.4	22.3
Alfalfa, first cutting	91.5	9.3	39.0	0.6	49.7	4.3	22.2	5.4	22.3
Alfalfa, second cutting	92.7	11.2	40.2	0.7	53.0	3.7	23.5	5.4	22.6

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the legumes—cont.									
Alfalfa, third cutting	91.1	10.2	37.1	0.8	49.1	3.8	23.4	5.3	22.2
Alfalfa, fourth cutting*	84.0	11.1	33.6	0.7	46.3	3.2	25.4	4.9	20.5
Alfalfa, before bloom*	93.8	15.4	35.5	1.6	54.5	2.5	35.2	....	....
Alfalfa, in bloom	92.5	10.5	38.5	0.7	50.6	3.8	24.0	....	....
Alfalfa, in seed*	89.6	8.5	39.2	1.0	49.9	4.9	19.5	....	....
Alfalfa, variegated, or sand lucerne*	84.8	10.1	35.2	0.8	47.1	3.7	22.7	....	....
Alfalfa meal*	91.2	10.2	38.7	0.8	50.7	4.0	22.9	5.4	22.3
Alfalfa leaves*	93.4	17.3	35.9	3.0	60.0	2.5	36.0	....	....
Alfalfa stems*	94.4	1.8	46.9	0.4	49.6	26.6	10.1	....	....
Bean, whole plant*	87.4	16.4	37.8	0.8	56.0	2.4	36.0	....	....
Beggarweed*	90.9	11.6	36.2	0.7	49.4	3.3	24.6	9.4	27.9
Clover, alsike, all analyses	87.7	7.9	36.9	1.1	47.3	5.0	20.5	7.0	17.4
Clover, alsike, in bloom	87.4	8.2	36.4	1.3	47.5	4.8	21.1	....	....
Clover, bur	93.0	15.6	42.8	0.2	58.8	2.8	30.7	....	....
Clover, crimson, or scarlet	89.4	9.7	36.8	1.0	48.7	4.0	22.6	6.1	22.4
Clover, Egyptian, or berseem*	92.5	8.5	40.9	1.4	52.6	5.2	23.0	6.3	24.7
Clover, mammoth red*	81.3	6.4	37.2	1.8	47.6	6.4	17.3	6.3	8.7
Clover, red, all analyses	87.1	7.6	39.3	1.8	50.9	5.7	20.5	3.9	16.3
Clover, red, before bloom*	89.6	11.6	38.1	1.9	54.0	3.7	29.9	7.4	22.1
Clover, red, in bloom	86.1	8.1	38.8	1.8	50.9	5.3	21.0	5.7	15.4
Clover, red, after bloom*	77.9	6.8	34.1	2.6	46.7	5.9	18.6	4.0	11.0
Clover, sweet, white	91.4	10.9	38.2	0.7	50.7	3.7	23.2	6.6	12.6
Clover, sweet, yellow*	91.3	10.0	35.9	0.5	47.0	3.7	21.4	....	....
Clover, white	91.9	11.8	43.3	1.5	58.5	4.0	25.9	5.2	20.0
Clover meal*	91.5	8.1	42.0	1.3	53.0	5.5	21.9	4.0	17.2
Clover rowen	85.2	10.7	33.1	2.2	48.8	3.6	26.4	....	....
Cowpea, all analyses	90.3	13.1	33.7	1.0	49.0	2.7	30.9	9.6	41.3
Cowpea, before bloom*	92.2	17.8	27.0	1.0	47.0	1.6	41.9	....	....
Cowpea, in bloom to early pod*	89.4	12.6	34.6	1.3	50.1	3.0	29.6	....	....
Cowpea, ripe*	90.0	6.9	42.1	1.0	51.2	6.4	16.2	....	....
Flat pea*	92.3	18.4	37.3	1.7	59.5	2.2	36.3	6.9	24.3
Kudzu vine*	93.3	12.4	37.7	1.1	52.6	3.2	29.3	6.2	....
Lespedeza, or Japan clover*	88.2	8.6	41.1	1.1	52.2	5.1	19.4	10.3	20.7
Lupines	92.2	11.8	44.3	1.9	60.4	4.1	25.3	....	....
Pea, field	88.9	12.2	40.1	1.9	56.6	3.6	24.2	6.7	12.4
Pea, field, without peas*	90.6	7.7	47.0	0.9	56.7	6.4	15.2	....	....
Peanut vine, mowed	81.9	7.0	38.4	3.3	52.8	6.5	15.5	....	....
Peanut vine, pulled, nuts removed	90.5	6.9	45.3	2.5	57.8	7.4	15.2	2.5	16.0
Peanut vine with nuts	92.2	9.4	37.7	10.6	71.0	6.6	21.0	....	....
Sanfoin	84.1	7.4	39.8	1.7	51.0	5.9	16.8	4.6	13.1
Serradella	90.3	11.8	35.1	1.6	50.5	3.3	25.1	10.3	15.1
Soybean hay	91.4	11.7	39.2	1.2	53.6	3.6	25.6	6.8	23.3

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the legumes—cont.									
Trefoil, yellow, or black medic*	88.8	12.0	37.5	1.1	52.0	3.3	27.0	5.7	8.1
Velvet bean*	92.8	12.0	40.3	1.4	55.5	3.6	26.2	5.5	26.5
Vetch, common	92.9	11.6	42.8	1.6	58.0	4.0	27.7	7.9	18.6
Vetch, hairy	87.7	15.7	37.1	1.9	57.1	2.6	31.8	10.3	26.2
Vetch, kidney*	90.3	8.1	43.1	1.0	53.4	5.6	19.4	8.9	13.4
Vetches, wild*	93.4	11.4	43.5	1.5	58.3	4.1	27.2	....	....
Hay from mixed legumes and grasses									
Clover and mixed grasses	89.9	4.7	39.9	1.3	47.5	9.1	15.8	4.1	20.0
Clover and timothy	87.8	4.0	39.7	1.1	46.2	10.6	13.8	4.7	19.0
Clover mixed rowen*	87.0	7.7	37.4	1.7	48.9	5.4	18.9	....	....
Cowpeas and millet*	90.3	9.3	34.7	0.9	46.0	3.9	21.9	....	....
Peas and oats	83.4	8.3	37.1	1.5	48.8	4.9	18.2	6.6	16.4
Peas, oats, and barley*	83.5	9.2	36.9	1.8	50.1	4.4	20.2	....	....
Vetch and oats	84.3	6.9	37.0	1.4	47.1	5.8	17.0	6.0	12.7
Vetch and wheat	85.0	10.7	41.1	1.3	54.7	4.1	23.2	....	....
Straw and chaff from the cereals									
Barley straw	85.8	0.9	40.2	0.6	42.5	46.2	5.6	1.8	12.0
Buckwheat straw*	90.1	4.2	26.3	1.2	33.2	6.9	8.3	1.3	11.3
Flax shives	92.8	5.8	25.2	3.0	37.8	5.5	11.5	1.9	10.5
Millet straw*	85.8	1.0	41.7	0.6	44.1	43.1	5.8	1.8	17.3
Oat straw	88.5	1.0	42.6	0.9	45.6	44.6	5.8	2.1	15.0
Oat chaff	91.8	2.2	34.3	1.2	39.2	16.8	9.4	1.3	4.5
Rice straw	92.5	0.9	37.8	0.3	39.4	42.8	6.2	1.4	15.4
Rye straw	92.9	0.7	39.6	0.4	41.2	57.9	4.8	2.8	7.9
Wheat straw	91.6	0.7	35.1	0.5	36.9	51.7	5.0	1.3	7.4
Wheat straw from rusted grain*	91.9	2.0	33.3	0.4	36.2	17.1	13.9	....	....
Wheat chaff	85.6	1.1	25.7	0.6	28.2	24.6	6.7	4.0	8.4
Legume straws									
Bean straw*	89.5	3.6	42.4	0.7	47.6	12.2	11.7	4.2	13.6
Pea straw, field	90.2	3.5	48.1	0.8	53.4	14.3	9.8	....	....
Crimson clover straw*	87.7	3.8	36.5	0.9	42.3	10.1	12.0	....	....
Cowpea straw*	91.5	3.4	39.1	0.7	44.1	12.0	10.9	....	....
Horse bean straw	87.9	4.2	38.2	0.8	44.2	9.5	13.8	3.0	20.3
Soybean straw	88.1	2.8	38.5	1.0	43.5	14.5	9.0	1.2	8.9
Miscellaneous dry roughages									
Alfilaria*	88.9	6.3	39.7	1.7	49.8	6.9	17.8	....	....
Artichoke tops*	74.2	2.7	50.8	0.3	54.2	19.1	6.7	2.9	10.5
Brush feed*	95.0	1.2	37.3	0.7	40.1	32.4	8.6	....	....
Burnet*	88.9	7.4	39.2	2.0	51.1	5.9	20.8	10.3	47.7
Daisy, field*	90.7	8.0	38.5	2.2	51.5	5.4	22.6	4.2	26.1
Furze*	94.5	2.7	32.3	0.6	36.4	12.5	18.6	6.5	24.4
Greasewood*	95.4	14.8	22.6	1.0	39.6	1.7	31.7	5.4	28.9
Prickly comfrey*	92.1	22.7	37.7	1.5	63.8	1.8	40.8	....	....
Purslane*	88.1	19.8	34.9	2.1	59.4	2.0	35.7	8.6	96.7
Rape*	88.7	16.8	47.2	1.6	67.6	3.0	30.2	12.6	46.8

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Miscellaneous dry roughages—cont.									
Russian thistle*	94.2	5.1	31.4	1.2	39.2	6.7	29.1	....	....
Saltbushes*	93.4	10.1	24.7	0.6	36.2	2.6	21.6	13.6	56.5
Spurrey*	92.1	7.9	41.5	3.0	56.2	6.1	18.1	....	....
Sweet potato vines*	88.7	6.0	37.1	1.6	46.7	6.8	20.0	5.4	16.4
FRESH GREEN ROUGHAGE									
Corn, the sorghums, etc.									
Corn fodder, all analyses*	21.9	1.0	12.8	0.4	14.7	13.7	3.0	1.1	3.7
Corn fodder, dent, all analyses	23.1	1.0	13.7	0.4	15.6	14.6	3.0	1.1	4.5
Corn fodder, dent, in tassel	14.9	1.1	8.2	0.3	10.0	8.1	2.6	....	....
Corn fodder, dent, in milk	19.9	1.0	12.1	0.5	14.2	13.2	2.6	....	....
Corn fodder, dent, dough to glazing*	25.1	1.3	15.4	0.7	18.3	13.1	3.4	....	....
Corn fodder, dent, kernels glazed	26.2	1.1	15.8	0.4	17.8	15.2	3.2	....	....
Corn fodder, dent, kernels ripe	34.8	1.5	21.1	0.8	24.4	15.3	4.3	....	....
Corn fodder, flint, all analyses	20.7	1.0	12.4	0.4	14.3	13.3	3.0	1.0	4.0
Corn fodder, flint, in tassel*	10.6	0.9	5.5	0.3	7.1	6.9	2.2	....	....
Corn fodder, flint, in milk*	15.0	0.9	8.9	0.4	10.7	10.9	2.4	....	....
Corn fodder, flint, kernels glazed	21.0	1.0	12.3	0.6	14.7	13.7	3.0	....	....
Corn fodder, flint, kernels ripe	27.9	1.2	16.6	0.7	19.4	15.2	3.8	....	....
Corn fodder, pop	16.9	0.8	9.9	0.3	11.4	13.2	2.1	....	....
Corn fodder, sweet, before milk stage*	10.0	0.8	6.1	0.2	7.3	8.1	1.6	0.5	1.9
Corn fodder, sweet, roasting ears or later	20.3	1.2	12.0	0.4	14.1	10.8	3.0	0.9	3.8
Corn fodder, sweet, ears removed*	21.5	1.0	13.1	0.3	14.8	13.8	2.6	....	....
Corn leaves and tops*	15.9	1.3	8.4	0.5	10.8	7.3	3.0	....	....
Corn husks*	36.5	1.0	22.7	0.3	24.4	23.4	2.9	0.6	5.5
Corn leaves*	31.1	2.1	16.5	0.6	20.0	8.5	5.1	1.0	7.1
Corn stover, green (ears removed)*	22.7	0.5	12.0	0.2	12.9	24.8	2.1	1.1	3.4
Broom-corn fodder*	22.9	0.9	12.1	0.3	13.7	14.2	3.2	1.7	7.0
Durra fodder*	22.4	0.9	12.0	0.4	13.8	14.3	3.2	1.8	5.6
Kafir fodder, all analyses*	23.6	1.1	12.4	0.4	14.4	12.1	3.8	1.6	5.1
Kafir fodder, heads just showing*	19.9	0.8	11.6	0.3	13.1	15.4	2.6	....	....
Milo fodder*	22.7	0.8	12.7	0.3	14.2	16.8	2.9	1.7	7.5
Sorghum fodder, sweet	24.9	0.7	14.8	0.7	17.1	23.4	2.4	1.1	4.1

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Corn, the sorghums, etc.—cont.									
Sugar cane*	21.7	0.4	12.3	0.6	14.1	34.2	1.4	....	....
Sweet corn ears, including husks*	37.8	3.0	24.4	1.9	31.7	9.6	6.1	4.0	4.8
Fresh green grass									
Bent grass, Canada, or bluejoint*	44.6	2.0	21.7	0.6	25.1	11.6	6.6	....	....
Bermuda grass*	33.2	1.4	17.0	0.5	19.5	12.9	4.8	1.5	7.4
Bluegrass, Canada*	33.2	1.3	17.2	0.4	19.4	13.9	4.8	1.8	6.9
Bluegrass, Kentucky, all analyses*	31.6	2.3	14.8	0.6	18.5	7.0	6.6	1.9	7.1
Bluegrass, Kentucky, before heading*	23.8	3.7	10.4	0.8	15.9	3.3	8.5	....	....
Bluegrass, Kentucky, headed out*	36.4	2.8	16.7	0.7	21.1	6.5	7.8	....	....
Bluegrass, Kentucky, after bloom*	43.6	1.9	21.9	0.7	25.4	12.4	5.4	....	....
Bluegrasses, native	45.3	2.0	20.7	0.6	24.1	11.0	5.1	....	....
Brome grass, smooth*	33.0	2.9	15.0	0.2	18.3	5.3	6.7	2.0	8.6
Brome grasses, miscellaneous	36.3	3.1	16.8	0.2	20.3	5.5	7.2	2.2	9.5
Bluejoint grasses, western*	38.9	1.7	17.6	0.4	20.2	10.9	4.2	....	....
Bluestem grasses*	31.6	1.9	13.2	0.8	16.9	7.9	4.8	....	....
Bunch grasses*	49.4	2.8	21.4	0.6	25.6	8.1	6.9	....	....
Chess or cheat*	39.6	1.5	20.8	0.6	23.7	14.8	5.1	2.9	7.7
Crab grass*	30.9	1.3	14.2	0.5	16.6	11.8	4.3	2.2	10.8
Fescue, meadow*	30.5	1.6	15.0	0.5	17.7	10.1	4.8	1.8	7.0
Fescues, native*	36.0	1.8	18.2	0.4	20.9	10.6	5.6	....	....
Guinea grass*	28.5	1.1	14.1	0.4	16.1	13.6	3.5	....	....
Grama grass*	36.1	2.1	15.7	0.4	18.7	7.9	5.3	....	....
Johnson grass*	29.1	1.2	14.7	0.5	17.0	13.2	4.0	....	....
Meadow foxtail*	29.6	2.1	13.9	0.6	17.4	7.3	5.8	....	....
Millet, barnyard	21.3	1.0	12.1	0.4	14.0	13.0	2.7	1.4	6.2
Millet, common, or Hungarian	27.6	1.9	14.8	0.6	18.1	8.5	4.6	1.2	6.9
Millet, hog, or broomcorn*	24.7	1.3	13.8	0.4	16.0	11.3	3.2	1.2	5.7
Millet, pearl or cat-tail*	18.7	1.1	10.4	0.2	11.9	9.8	2.9	1.9	10.3
Mixed grasses, immature	29.7	3.6	14.5	0.9	20.1	4.6	8.2	2.1	7.9
Mixed grasses, at haying stage	30.8	1.7	15.2	0.6	18.3	9.8	4.8	2.5	6.4
Oat grass, tall, or meadow oat grass*	30.3	1.1	13.3	0.4	15.3	12.9	4.2	1.8	8.4
Orchard grass	29.2	1.7	13.0	0.6	16.1	8.5	4.6	2.1	9.5
Para grass*	27.2	0.8	14.0	0.3	15.5	18.4	2.7	....	....
Quack grass*	25.0	2.2	11.3	0.7	15.1	5.9	6.1	....	....
Rescue grass*	30.6	2.6	14.5	0.2	17.5	5.7	6.1	1.9	5.3
Red top	39.3	1.9	20.0	0.6	23.3	11.3	5.0	2.3	8.4
Reed canary grass*	37.0	1.7	18.3	0.6	21.4	11.6	5.8	2.3	9.8
Reed meadow grass*	30.7	1.3	15.4	0.3	17.4	12.4	4.5	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Fresh green grass—cont.									
Rhode Island bent grass*	32.7	1.4	16.4	0.4	18.7	12.4	4.6	2.2	8.6
Rowen, mixed	28.2	3.3	14.0	0.9	19.3	4.8	7.5	2.0	7.5
Rye grass, Italian*	27.1	1.8	12.7	0.7	16.1	7.9	5.0	2.0	7.5
Rye grass, perennial*	26.6	1.7	12.5	0.7	15.8	8.3	4.8	2.2	9.2
Rushes, western*	31.1	2.5	16.2	0.3	19.4	6.8	5.4	....	....
Sedges, western*	38.5	2.4	20.3	0.5	23.8	8.9	6.1	....	....
Spear grasses, miscellaneous*	43.6	2.0	23.6	0.4	26.5	12.2	5.3	1.6	8.0
Sudan grass*	22.5	0.8	11.8	0.4	13.5	15.9	2.9	....	....
Sweet vernal grass*	31.2	1.5	16.1	0.5	18.7	11.5	4.2	2.0	6.4
Teosinte*	21.3	1.0	11.9	0.3	13.6	12.6	2.7	2.0	9.3
Timothy, all analyses	37.5	1.5	19.3	0.6	22.2	13.8	5.0	1.8	6.7
Timothy, before bloom*	24.2	1.8	13.8	0.4	16.5	8.2	4.0	....	....
Timothy, in bloom	32.1	1.3	16.4	0.5	18.8	13.5	4.3	....	....
Timothy, in seed	46.4	1.5	24.7	0.7	27.8	17.5	5.0	....	....
Timothy, mountain*	37.5	1.4	19.6	0.5	22.1	14.8	4.8	....	....
Wheat grasses, miscellaneous*	45.3	2.2	24.1	0.5	27.4	11.5	6.4	....	....
Wild barley*	35.7	2.4	15.9	0.7	19.9	7.3	7.8	....	....
Wild oats*	36.6	1.5	18.7	0.7	21.8	13.5	4.2	....	....
Wild rye*	23.3	2.1	10.4	0.5	13.6	5.5	5.9	....	....
Green fodder from the smaller cereals									
Barley fodder	23.2	2.3	11.5	0.4	14.7	5.4	5.3	1.3	6.8
Buckwheat, Japanese*	36.6	2.2	17.4	0.5	20.7	8.4	7.4	2.0	9.3
Oat fodder	26.1	2.3	11.8	0.8	15.9	5.9	5.1	1.8	7.7
Oat fodder, 8 in. high*	13.0	3.4	4.1	0.5	8.6	1.5	7.8	....	....
Rye fodder	21.3	2.1	12.2	0.5	15.4	6.3	4.2	1.5	4.9
Rye fodder, 5 in. high	18.1	5.1	6.2	0.7	12.9	1.5	10.4	....	....
Wheat fodder, all analyses*	27.4	2.8	15.1	0.6	19.3	5.9	5.8	1.9	7.2
Wheat fodder, 5 in. high*	24.2	5.1	10.3	0.5	16.5	2.2	10.4	....	....
Green legumes									
Alfalfa, all analyses	25.3	3.3	10.4	0.4	14.6	3.4	7.2	1.5	6.7
Alfalfa, before bloom*	19.9	3.5	7.5	0.3	11.7	2.3	7.5	....	....
Alfalfa, in bloom*	25.9	3.3	10.8	0.3	14.8	3.5	7.0	....	....
Alfalfa, after bloom*	29.8	2.1	13.5	0.2	16.0	6.6	4.6	1.7	7.9
Beggarweed*	27.1	3.1	11.6	0.2	15.1	3.9	6.7	2.7	5.7
Clover, alsike*	24.3	2.7	11.8	0.4	15.4	4.7	6.6	1.8	9.2
Clover, alsike, in bloom*	21.5	2.3	10.4	0.4	13.6	4.9	5.6	....	....
Clover, bur*	20.8	3.4	8.2	1.1	14.1	3.1	8.2	....	....
Clover, crimson	17.4	2.3	8.1	0.4	11.3	3.9	4.8	2.0	4.1
Clover, mammoth red*	25.1	2.7	12.4	0.3	15.8	4.9	6.4	....	....
Clover, red, all analyses	26.2	2.7	13.0	0.6	17.1	5.3	6.6	1.3	5.6
Clover, red, in bloom*	27.5	2.7	13.8	0.7	18.1	5.7	6.6	....	....
Clover, red, rowen	34.4	3.3	15.4	0.8	20.5	5.2	8.5	2.0	9.5
Clover, sweet*	24.4	3.3	10.3	0.3	14.3	3.3	7.0	1.3	5.0
Clover, white*	21.8	3.1	9.6	0.5	13.8	3.5	7.4	1.8	8.1
Cowpeas	16.3	2.3	8.0	0.3	11.0	3.8	4.8	1.4	6.2

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Green legumes—cont.									
Flat pea*	22.5	4.6	9.1	0.4	14.6	2.2	9.1	1.5	4.6
Jack bean*	23.2	4.0	9.2	0.3	13.9	2.5	8.3	....	....
Horse bean*	17.6	2.8	7.4	0.3	10.9	2.9	5.8	1.2	3.7
Kudzu vine*	30.6	4.2	13.9	0.5	19.2	3.6	8.8	....	....
Lespedeza or Japan clover*	36.6	4.5	17.1	0.6	23.0	4.1	10.7	....	....
Lupines	17.4	2.6	8.0	0.3	11.3	3.3	5.4	0.9	5.1
Peas, field, Canada	16.6	2.9	7.1	0.3	10.7	2.7	5.8	1.1	2.8
Peas, field, miscellaneous*	18.8	2.6	8.6	0.3	11.9	3.6	5.1	1.2	3.2
Sanfoin	25.6	2.8	12.3	0.5	16.2	4.8	6.1	1.4	4.0
Serradella*	20.2	2.1	8.9	0.5	12.1	4.8	4.6	1.3	4.1
Soybeans, all analyses	23.6	3.2	10.2	0.5	14.5	3.5	6.6	1.8	5.7
Soybeans, in bloom*	20.8	3.0	8.5	0.3	12.2	3.1	6.2	....	....
Soybeans, in seed*	24.2	3.1	10.7	0.5	14.9	3.8	6.4	....	....
Trefoil, yellow, or black medic*	22.7	3.3	9.2	0.3	13.2	3.0	7.2	....	....
Velvet bean*	17.9	2.7	7.2	0.4	10.8	3.0	5.6	1.3	4.5
Vetch, common	20.4	2.7	8.9	0.3	12.3	3.6	6.1	1.6	5.0
Vetch, kidney*	27.7	2.6	12.8	0.3	16.1	5.2	5.9	....	....
Vetch, hairy	18.1	3.5	8.1	0.4	12.5	2.6	6.7	1.4	5.1
Vetches, wild*	24.6	4.2	12.1	0.4	17.2	3.1	8.2	1.7	6.0
Mixed legumes and grasses									
Clover and mixed grasses*	27.3	2.2	14.1	0.6	17.7	7.0	4.8	....	....
Cowpeas and corn*	20.0	1.3	11.4	0.3	13.4	9.3	3.4	....	....
Cowpeas and oats*	21.8	3.3	9.1	0.6	13.8	3.2	7.2	....	....
Cowpeas and sorghum*	18.7	0.7	10.0	0.3	11.4	15.3	2.4	....	....
Peas and millet*	19.7	1.9	8.4	0.8	12.1	5.4	4.2	....	....
Peas and barley	20.2	2.7	8.8	0.5	12.6	3.7	5.8	1.6	5.9
Peas and oats	22.6	2.4	10.6	0.6	14.4	5.0	5.1	1.7	6.1
Peas, oats, and rape*	17.9	2.3	7.3	0.5	10.7	3.7	5.0	1.0	4.4
Soybeans and corn*	23.8	1.7	13.6	0.6	16.7	8.8	4.3	1.1	4.0
Soybeans and kafir*	17.1	0.9	7.9	0.4	9.7	9.8	3.2	....	....
Vetch and barley*	20.0	2.1	10.5	0.2	13.0	5.2	4.5	....	....
Vetch and oats	26.5	2.8	13.3	0.4	17.0	5.1	6.1	1.6	6.3
Vetch and wheat	22.7	2.4	12.2	0.3	15.3	5.4	5.3	....	....
Roots and tubers									
Artichokes*	20.5	1.0	14.6	0.1	15.8	14.8	3.2	1.4	4.9
Beet, common*	13.0	0.9	9.1	0.1	10.2	10.3	2.6	1.0	8.5
Beet, sugar	16.4	1.2	12.6	0.1	14.0	10.7	2.6	0.8	3.2
Carrot	11.7	1.0	9.1	0.2	10.6	9.6	1.9	1.1	2.7
Cassava*	32.6	0.6	26.4	0.2	27.4	44.7	1.8	1.0	4.0
Chufa*	20.5	0.4	10.2	3.3	18.0	44.0	1.1	....	....
Mangel	9.4	0.8	6.4	0.1	7.4	8.2	2.2	0.4	2.2
Onion*	12.4	0.8	9.6	0.2	10.8	12.5	2.1	0.9	2.2
Parsnip*	16.6	1.3	12.5	0.4	14.7	10.3	2.7	1.3	4.9
Potato	21.2	1.1	15.8	0.1	17.1	14.5	3.5	1.2	5.3
Rutabaga	10.9	1.0	7.7	0.3	9.4	8.4	1.9	1.2	5.0
Sweet potato*	31.2	0.9	24.2	0.3	25.8	27.7	2.9	0.9	5.1
Turnip	9.5	1.0	6.0	0.2	7.4	6.4	2.2	1.3	2.9

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—cont.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Miscellaneous green forages									
Alfilaria*	16.3	2.2	7.0	0.2	9.6	3.4	5.1	....	....
Apple*	18.2	0.4	15.6	0.2	16.4	40.0	0.8	0.3	1.6
Apple pomace*	23.3	1.2	15.6	0.8	18.6	14.5	2.6	0.6	1.5
Burnet*	19.9	2.7	12.8	0.3	16.2	5.0	4.8	2.1	8.8
Cabbage	8.9	1.9	5.6	0.2	7.9	3.2	3.5	0.7	2.9
Cabbage waste, outer leaves	14.1	1.7	6.5	0.1	8.4	3.9	4.3	....	....
Cactus, cane, entire plant*	10.4	0.4	5.8	0.1	6.4	15.0	1.4	0.3	2.1
Cactus, cane, fruit*	18.6	0.8	9.9	0.5	11.8	13.8	2.4	....	....
Cactus, cane, stems*	21.7	0.8	11.8	0.3	13.3	15.6	2.4	0.8	4.8
Cactus, prickly pear	16.5	0.4	8.9	0.2	9.7	23.2	1.3	0.7	4.3
Cactus, prickly pear, old joints*	16.4	0.3	9.1	0.2	9.8	31.7	1.0	0.6	4.0
Cactus, prickly pear, young joints*	12.9	0.4	6.9	0.3	8.0	19.0	1.4	0.5	3.3
Kale	11.3	1.9	4.7	0.3	7.3	2.8	3.8	....	....
Kohlrabi*	9.0	1.7	5.6	0.1	7.5	3.4	3.2	....	....
Melon, pie, or stock*	6.1	0.5	3.9	0.2	4.8	8.6	1.1	....	....
Mustard, white*	14.0	3.6	6.5	0.3	10.8	2.0	6.6	....	....
Potato pomace, wet*	8.3	0.4	6.0	0.1	6.6	15.4	1.1	1.3	3.0
Prickly comfrey*	12.8	2.2	7.0	0.1	9.4	3.3	4.0	1.8	9.5
Pumpkin, field	8.3	1.1	4.5	0.5	6.7	5.1	2.2	0.9	3.2
Purslane*	10.3	2.0	5.4	0.1	7.6	2.8	3.5	1.0	11.3
Rape	16.7	2.6	10.0	0.3	13.3	4.1	4.6	1.1	3.9
Russian thistle*	20.4	2.2	7.6	0.2	10.2	3.6	4.8	....	....
Saltbush, Australian*	23.3	2.8	5.9	0.2	9.1	2.2	5.9	3.4	14.1
Saltbushes, miscellaneous*	24.3	2.9	6.6	0.1	9.7	2.3	6.2	....	....
Sugar beet leaves*	11.6	1.2	6.3	0.1	7.7	5.4	3.0	1.2	5.5
Sugar beet tops*	11.4	1.7	5.4	0.1	7.3	3.3	4.2	1.0	6.4
Sunflower, Russian whole plant*	16.6	0.7	7.7	0.4	9.3	12.3	2.2	....	....
Turnip tops*	15.0	1.8	7.3	0.1	9.3	4.2	4.5	1.5	5.2
SILAGE									
Silage from corn, the sorghums, etc.									
Corn, well matured, recent analyses	26.3	1.1	15.0	0.7	17.7	15.1	3.4	1.6	4.4
Corn, immature	21.0	1.0	11.4	0.4	13.3	12.3	3.0	1.2	3.5
Corn, early analyses	23.1	1.0	12.6	0.6	15.0	14.0	3.0	1.4	3.9
Corn, from frosted corn*	25.3	1.2	13.7	0.6	16.3	12.6	3.5	1.5	4.3
Corn, stover*	20.6	0.6	10.7	0.4	12.2	19.3	2.4	....	....
Darso	26.9	0.8	14.1	0.2	15.4	18.2	3.0	....	....
Durra*	20.3	0.6	9.9	0.4	11.4	18.0	1.9	....	....
Kafir	30.8	0.8	15.3	0.6	17.5	20.9	2.9	....	....
Sorghum	22.8	0.6	11.6	0.5	13.3	21.2	2.4	1.5	1.9
Japanese cane*	22.4	0.6	11.2	0.3	12.5	19.8	2.4	....	....
Sugar-cane tops*	23.5	0.5	12.2	0.2	13.1	25.2	1.9	....	....

TABLE III. Digestible nutrients and fertilizing constituents—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
SILAGE—cont. *Miscellaneous silage*	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Alfalfa, wilted before ensiling	54.0	5.1	20.4	1.6	29.1	4.7	16.0	....	....
Alfalfa, high in water	25.0	2.0	8.9	1.0	13.2	5.6	6.2	....	....
Apple pomace*	20.6	0.9	15.0	0.6	17.3	18.2	2.6	0.8	2.2
Barley*	25.0	2.0	12.0	0.8	15.8	6.9	4.2	....	....
Clover, red	24.4	2.0	9.6	0.8	13.4	5.7	6.2	....	....
Corn and clover*	28.6	2.1	15.9	0.7	19.6	8.3	5.3	....	....
Corn and rye*	19.4	1.1	10.0	1.0	13.3	11.1	3.4	....	....
Corn and soybean	25.1	1.6	14.0	0.8	17.4	9.9	4.2	1.6	4.7
Cowpea	21.2	1.8	9.7	0.5	12.6	6.0	5.0	1.7	3.7
Cowpea and soybean*	28.5	1.9	13.2	0.7	16.7	7.8	5.4	1.7	5.6
Field pea*	27.9	2.8	13.1	0.9	17.9	5.4	6.1	2.9	2.3
Millet*	31.6	1.6	15.3	0.8	18.7	10.7	4.5	....	....
Millet, barnyard, and soybean	21.0	1.6	9.2	0.7	12.4	6.8	4.5	....	....
Mixed grasses*	30.7	1.3	15.0	0.6	17.7	12.6	3.7	....	....
Mung bean, nearly mature*	13.3	1.8	10.9	0.8	14.5	7.1	5.0	....	....
Oat*	28.3	1.5	13.8	0.9	17.3	10.5	3.2	....	....
Oat and pea	27.5	2.8	12.6	1.0	17.6	5.3	6.1	1.7	7.0
Pea-cannery refuse*	23.2	1.6	11.6	0.8	15.0	8.4	4.5	....	....
Rye*	26.9	2.6	15.5	0.6	19.4	6.5	5.3	1.7	6.8
Sorghum and cowpea*	32.3	0.9	16.6	0.6	18.9	20.0	3.8	....	....
Soybean	27.2	2.8	10.8	0.9	15.6	4.6	6.7	1.7	7.1
Sudan grass	25.3	1.1	13.1	0.4	15.1	12.7	3.8	....	....
Sugar beet pulp*	10.0	0.8	6.5	0.3	8.0	9.0	2.4	....	....
Sugar beet tops	28.8	1.4	7.3	0.3	9.4	5.7	5.1	....	....
Sunflower	21.9	1.0	9.8	0.8	12.6	11.6	3.2	....	....
Vetch	30.1	2.0	15.2	0.8	19.0	8.5	5.6	....	....
Velvet bean*	23.6	2.5	10.7	0.8	15.0	5.0	6.9	....	....

Table IV. Wolff-Lehmann Feeding Standards for Farm Animals

The Wolff-Lehmann Feeding Standards have been fully discussed in a preceding chapter. (**156-7, 168, 187-8**) It is there pointed out that we now have much more accurate and extensive data on the nutrients required by the various classes of farm animals than was possessed by the scientists many years ago when these standards were drawn up. As the Wolff-Lehmann Standards are in many instances inaccurate and do not meet American conditions, they should not now be used in figuring out rations for practical stock feeding. Instead the Morrison (or Modified Wolff-Lehmann) Standards, given in Appendix Table V, or one of the other up-to-date standards discussed in Chapter VII should be used, as these have been designed to meet present day conditions. The Wolff-Lehmann Standards, as last presented by Lehmann in the Mentzel and Lengerke Agricultural Calendar for 1906, are here given, however, because historically this table is worthy of a place in any book on the feeding of farm animals.

The standards for milk cows are given for the middle of the lactation period with animals yielding milk of average composition. The standards for growing animals contemplate only a moderate amount of exercise; if much is taken, add 15 per cent—mostly non-nitrogenous nutrients—to the ration. If no exercise is taken, deduct 15 per cent from the standard. The standards are for animals of normal size. Those of small breeds will require somewhat more nutrients, amounting in some cases to 0.3 of a pound of nitrogenous and 1.5 pounds of non-nitrogenous digestible nutrients daily for 1,000 pounds of live weight of animals.

Animal	Per day per 1,000 lbs. live weight				
	Dry matter	Digestible nutrients			
		Crude protein	Carbohydrates	Fat	Nutritive ratio
1. Oxen	Lbs.	Lbs.	Lbs.	Lbs.	1:
At rest in stall	18	0.7	8.0	0.1	11.8
At light work	22	1.4	10.0	0.3	7.7
At medium work	25	2.0	11.5	0.5	6.5
At heavy work	28	2.8	13.0	0.8	5.3
2. Fattening cattle					
First period	30	2.5	15.0	0.5	6.5
Second period	30	3.0	14.5	0.7	5.4
Third period	26	2.7	15.0	0.7	6.2
3. Milk cows, yielding daily					
11.0 pounds of milk	25	1.6	10.0	0.3	6.7
16.6 pounds of milk	27	2.0	11.0	0.4	6.0
22.0 pounds of milk	29	2.5	13.0	0.5	5.7
27.5 pounds of milk	32	3.3	13.0	0.8	4.5
4. Sheep					
Coarse wool	20	1.2	10.5	0.2	9.1
Fine wool	23	1.5	12.0	0.3	8.5
5. Breeding ewes					
With lambs	25	2.9	15.0	0.5	5.6
6. Fattening sheep					
First period	30	3.0	15.0	0.5	5.4
Second period	28	3.5	14.5	0.6	4.5
7. Horses					
Light work	20	1.5	9.5	0.4	7.0
Medium work	24	2.0	11.0	0.6	6.2
Heavy work	26	2.5	13.3	0.8	6.0
8. Brood sows	22	2.5	15.5	0.4	6.6
9. Fattening swine					
First period	36	4.5	25.0	0.7	5.9
Second period	32	4.0	24.0	0.5	6.3
Third period	25	2.7	18.0	0.4	7.0

TABLE IV. Wolff-Lehmann feeding standards for farm animals—*continued.*

Animal	Per day per 1,000 lbs. live weight				
	Dry matter	Digestible nutrients			
		Crude protein	Carbo-hy-drates	Fat	Nutri-tive ratio
10. Growing cattle, dairy breeds	Lbs.	Lbs.	Lbs.	Lbs.	1:
Age in months / Av. live wt. per head, lbs.					
2– 3 ... 150	23	4.0	13.0	2.0	4.5
3– 6 ... 300	24	3.0	12.8	1.0	5.1
6–12 ... 500	27	2.0	12.5	0.5	6.8
12–18 ... 700	26	1.8	12.5	0.4	7.5
18–24 ... 900	26	1.5	12.0	0.3	8.5
11. Growing cattle, beef breeds					
2– 3 ... 160	23	4.2	13.0	2.0	4.2
3– 6 ... 330	24	3.5	12.8	1.5	4.7
6–12 ... 550	25	2.5	13.2	0.7	6.0
12–18 ... 750	24	2.0	12.5	0.5	6.8
18–24 ... 950	24	1.8	12.0	0.4	7.2
12. Growing sheep, wool breeds					
4– 6 ... 60	25	3.4	15.4	0.7	5.0
6– 8 ... 75	25	2.8	13.8	0.6	5.4
8–11 ... 80	23	2.1	11.5	0.5	6.0
11–15 ... 90	22	1.8	11.2	0.4	7.0
15–20 ... 100	22	1.5	10.8	0.3	7.7
13. Growing sheep, mutton breeds					
4– 6 ... 60	26	4.4	15.5	0.9	4.0
6– 8 ... 80	26	3.5	15.0	0.7	4.8
8–11 ... 100	24	3.0	14.3	0.5	5.2
11–15 ... 120	23	2.2	12.6	0.5	6.3
15–20 ... 150	22	2.0	12.0	0.4	6.5
14. Growing swine, breeding stock					
2– 3 ... 50	44	7.6	28.0	1.0	4.0
3– 5 ... 100	35	4.8	22.5	0.7	5.0
5– 6 ... 120	32	3.7	21.3	0.4	6.0
6– 8 ... 200	28	2.8	18.7	0.3	7.0
8–12 ... 250	25	2.1	15.3	0.2	7.5
15. Growing, fattening swine					
2– 3 ... 50	44	7.6	28.0	1.0	4.0
3– 5 ... 100	35	5.0	23.1	0.8	5.0
5– 6 ... 150	33	4.3	22.3	0.6	5.5
6– 8 ... 200	30	3.6	20.5	0.4	6.0
9–12 ... 300	26	3.0	18.3	0.3	6.4

Table V. Morrison (or Modified Wolff-Lehmann) Feeding Standards for Farm Animals

It has been pointed out on previous pages that the recent investigations of the experiment stations of this and other countries have shown that the original Wolff-Lehmann standards are in many instances decidedly inaccurate. (**187-90**) To provide a means by which rations can be computed substantially in accordance with this well-known system, but yet taking into consideration the results of the recent scientific work on live stock feeding, the following standards have been prepared. The sources of the recommendations here given for the various classes of animals are stated in Chapter VII, and the methods of computing rations in accordance with these standards are fully explained in Chapter VII (**189-90**) and in Chapter VIII.

In all cases both a minimum and a maximum are given for dry matter, digestible crude protein, and total digestible nutrients. As has been pointed out in the text (**146**), when protein-rich feeds are cheaper than carbonaceous feeds, somewhat more digestible crude protein may be supplied than is stated in the standards. This will narrow the nutritive ratio beyond the limits here indicated. On the other hand, the amount of protein should not fall much below the lower amount indicated.

These recommendations are presented, not as final, arbitrary standards, but as the best available guides we have at present in the scientific feeding of live stock, based on the older standards, but changed to conform to recent scientific data and to the practical experience of the most successful stockmen.

Computing economical rations.—Before attempting to work out economical balanced rations for any class of stock, it is important to study carefully the explanations and general hints in Articles **158–167** and **191–200.** It is impossible to compute satisfactory and profitable balanced rations if reliance is placed only on the mathematical recommendations of any feeding standard. As is explained in the articles referred to, several other factors are just as important in determining the efficiency of a ration as the amounts of digestible crude protein and of total digestible nutrients.

The special rules and hints on feeding each class of stock, which are given in the respective chapters of Part III, should also be carefully consulted. For convenience the following references to important articles discussing balanced rations for the various farm animals are given:

Dairy cows, **645–51.**
Fattening steers, **710, 715–7, 800.**
Beef breeding cows, **788–90.**
Horses, **455–6, 530, 536.**
Brood mares, **514.**
Growing colts, **519–25.**
Fattening lambs, **901–7.**
Breeding ewes, **882–4.**
Growing, fattening pigs, **914–7, 1030–5, 1037.**
Brood sows, **1012–23.**

Morrison Feeding Standards for Farm Animals

	Digestible crude protein	Total digestible nutrients
1. *Dairy cows*	Lbs.	Lbs.
For maintenance of 1000-lb. cow	0.700	7.925
To allowance for maintenance add:		
For each lb. of 2.5 per ct. milk	0.045–0.053	0.230–0.256
For each lb. of 3.0 per ct. milk	0.047–0.057	0.257–0.286
For each lb. of 3.5 per ct. milk	0.049–0.061	0.284–0.316
For each lb. of 4.0 per ct. milk	0.054–0.065	0.311–0.346
For each lb. of 4.5 per ct. milk	0.057–0.069	0.338–0.376
For each lb. of 5.0 per ct. milk	0.060–0.073	0.362–0.402
For each lb. of 5.5 per ct. milk	0.064–0.077	0.385–0.428
For each lb. of 6.0 per ct. milk	0.067–0.081	0.409–0.454
For each lb. of 6.5 per ct. milk	0.072–0.085	0.434–0.482
For each lb. of 7.0 per ct. milk	0.074–0.089	0.454–0.505

Notes on standards for dairy cows.—The amount of dry matter to be fed daily per 1,000 lbs. live weight to dairy cows may range from 15.0 lbs. or even less with dry cows to 30.0 lbs. with cows yielding 2.0 lbs. of butter fat per head daily. Cows producing 1.0 lb. of fat per head daily should receive about 21.0 to 25.0 lbs. of dry matter daily per

1,000 lbs. live weight. The nutritive ratio may readily be found by computation; for example, a 1,200-lb. cow yielding daily 30.0 lbs. of 3.5 per ct. milk will require for maintenance and production 2.31 to 2.67 lbs. digestible crude protein and 18.03 to 18.99 lbs. total digestible nutrients. The nutritive ratio should hence not be wider than 1:6.1 to 1:7.2.

Feeding the higher amounts of protein recommended will usually increase the production slightly, but may not be economical if protein-rich feeds are higher in price than those rich in carbohydrates. Also, the production will be slightly larger if sufficient concentrates are fed to bring the amount of total digestible nutrients to the higher figures recommended. However, with feeds at high prices, it may be economical to feed no more concentrates than necessary to meet the lower figures for total digestible nutrients. (**196–7, 573**)

Notes on standards for other classes of animals.—The standards given under Division 3 on this page for growing, fattening steers weighing 1,000 to 1,200 lbs. are for animals being finished on only a moderate allowance of concentrates. It will be noted that the amount of total digestible nutrients is considerably lower than the amount indicated under Division 4 for fattening 2-yr.-old steers on full feed. As has been pointed out in the text, cattle fed a small amount of concentrates will not make maximum gains. Whether or not it will be most profitable to restrict the amount of concentrates fed to fattening cattle will depend on the various factors discussed in the text. (**915–7**)

TABLE V. MORRISON FEEDING STANDARDS—*continued.*

Animal	Per day per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	1:
2. Growing dairy cattle				
Weight 100–200 lbs.	22.0–24.0	2.9–3.2	17.0–19.0	4.5–5.2
Weight 200–300 lbs.	23.0–25.0	2.6–2.9	16.5–18.5	5.2–5.9
Weight 300–400 lbs.	24.0–26.0	2.3–2.6	15.5–17.5	5.9–6.5
Weight 400–500 lbs.	22.0–25.0	2.0–2.3	14.5–16.5	6.3–6.8
Weight 500–600 lbs.	21.5–24.5	1.8–2.0	13.8–15.8	6.5–7.0
Weight 600–700 lbs.	21.0–24.0	1.7–1.9	13.0–15.0	6.6–7.2
Weight 700–800 lbs.	20.5–23.5	1.6–1.8	12.2–14.2	6.7–7.3
Weight 800–900 lbs.	20.0–23.0	1.5–1.7	11.4–13.4	6.9–7.5
Weight 900–1,000 lbs.	20.0–23.0	1.3–1.5	10.6–12.6	7.0–7.6
3. Growing, fattening steers				
Weight 100–200 lbs.	22.0–24.0	2.9–3.2	17.0–19.0	4.5–5.2
Weight 200–300 lbs.	23.0–25.0	2.6–2.9	16.8–18.8	5.2–5.9
Weight 300–400 lbs.	24.0–26.0	2.3–2.6	15.6–17.6	5.9–6.5
Weight 400–500 lbs.	24.0–26.0	2.1–2.3	15.1–17.1	6.4–6.9
Weight 500–600 lbs.	23.0–25.0	2.0–2.2	14.7–16.7	6.6–7.1
Weight 600–700 lbs.	22.0–24.0	1.9–2.1	14.3–16.3	6.7–7.2
Weight 700–800 lbs.	21.0–23.0	1.8–2.0	14.0–16.0	6.8–7.3
Weight 800–900 lbs.	20.5–22.5	1.7–1.9	13.6–15.6	6.9–7.5
Weight 900–1,000 lbs.	20.0–22.0	1.6–1.8	13.2–15.2	7.0–7.6
Weight 1,000–1,100 lbs.	19.5–21.5	1.5–1.7	12.7–14.7	7.0–7.8
Weight 1,100–1,200 lbs.	19.0–21.0	1.4–1.6	12.3–14.3	7.0–8.0
4. Fattening 2-year-old steers on full feed				
First 40–60 days	22.0–25.0	1.8–2.1	16.5–18.5	7.0–8.0
Second 40–60 days	20.0–23.0	1.8–2.0	16.0–18.0	7.0–8.0
Third 40–60 days	18.0–21.0	1.7–1.9	15.5–17.5	7.0–8.0
5. Ox at rest in stall	13.0–21.0	0.6–0.8	8.4–10.4	10.0–16.0
6. Wintering beef cows in calf	14.0–25.0	0.7–0.9	9.0–12.0	10.0–15.0

TABLE V. MORRISON FEEDING STANDARDS—*continued.*

Animal	Per day per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	1:
7. *Horses*				
Idle	13.0–18.0	0.8–1.0	7.0– 9.0	8.0–9.0
At light work	15.0–20.0	1.0–1.2	9.0–11.0	8.0–8.5
At medium work	16.0–21.0	1.2–1.5	11.0–13.0	7.8–8.3
At heavy work	18.0–22.0	1.5–1.8	13.0–15.0	7.6–8.1
8. *Brood mares suckling foals, but not at work*	15.0–22.0	1.2–1.5	9.0–12.0	6.5–7.5
9. *Growing colts, over 6 months*	18.0–22.0	1.6–1.8	11.0–13.0	6.0–7.0
10. *Fattening lambs*				
Weight 50–70 lbs.	27.0–30.0	2.7–3.0	19.0–22.0	6.0–6.7
Weight 70–90 lbs.	28.0–31.0	2.5–2.8	20.0–23.0	6.7–7.2
Weight 90–110 lbs.	27.0–31.0	2.3–2.5	19.0–23.0	7.0–8.0
11. *Sheep, maintaining, mature*				
Coarse wool	18.0–23.0	1.1–1.3	11.0–13.0	8.0–9.1
Fine wool	20.0–26.0	1.4–1.6	12.0–14.0	7.5–8.5
12. *Breeding ewes, with lambs*	23.0–27.0	2.6–2.9	18.0–20.0	5.6–6.5
13. *Fattening pigs*				
Weight 30–50 lbs.	46.2–51.0	7.8–8.5	41.0–45.4	4.0–4.5
Weight 50–100 lbs.	37.0–40.8	5.5–6.0	32.9–36.4	5.0–5.6
Weight 100–150 lbs.	32.4–35.8	4.4–4.9	28.8–31.9	5.5–6.2
Weight 150–200 lbs.	29.0–32.0	3.5–3.9	25.8–28.5	6.2–7.0
Weight 200–250 lbs.	25.5–28.1	3.0–3.4	22.7–25.0	6.5–7.3
Weight 250–300 lbs.	22.4–24.8	2.6–2.9	20.0–22.0	6.7–7.5
14. *Brood sows, with pigs*	20.0–24.0	2.4–2.7	18.0–21.0	6.0–7.0

Table VI. Net Energy Values of Feeding Stuffs for Ruminants

For the convenience of those desiring to compute rations in accordance with the Armsby Feeding Standards (**171–7**), the following table is given. This includes most of the net energy values for ruminants computed by Armsby with the special permission of the authors of this volume, from the average content of digestible nutrients given in Appendix Table III of this book. The figures for dry matter and digestible crude protein are taken directly from Appendix Table III of this book, while those for digestible true protein were computed by Armsby from the figures for digestible crude protein and other data. The net energy values of a few of the important feeds for horses are given on Page 287. But little reliable data of this sort is available for swine.

It should be borne in mind that the Armsby feeding standards are based on digestible true protein, instead of digestible crude protein. Thus these standards ignore the value of the "amids" in feeding stuffs as nitrogenous nutrients for the repair or growth of the protein tissues of the body, or for the production of the proteins in milk. As has been pointed out, this is not in accord with the results of the recent investigations with reference to the nutritive value of the nitrogenous compounds of feeds. (**94**)

Net energy values per 100 lbs. of various feeding stuffs

	Dry matter	Digestible		Net energy value
		Crude protein	True protein	
Concentrates	Lbs.	Lbs.	Lbs.	Therms
Grains and seeds				
Barley	90.7	9.0	8.3	89.94
Buckwheat	87.9	8.1	7.2	59.73
Corn, dent	89.5	7.5	7.0	85.50
Corn, flint	87.8	7.7	7.2	84.00
Corn-and-cob meal	89.6	6.1	5.7	75.80
Cotton seed	90.6	13.3	11.9	78.33
Cowpea	88.4	19.4	16.9	79.46
Flax seed	90.8	20.6	19.2	83.17
Oats	90.8	9.7	8.7	67.56
Peanut, with hull	93.5	19.4	16.9	83.15
Pea, field	90.8	19.0	16.6	78.72
Rice, rough	90.4	4.7	4.5	77.33
Rye	90.6	9.9	9.0	93.71
Sorghum grain	87.3	7.5	6.7	89.75
Soybean	90.1	30.7	27.3	81.29
Wheat, all analyses	89.8	9.2	8.1	91.82
Wheat, spring	89.9	9.2	8.1	91.41
Wheat, winter	89.1	8.7	7.7	91.66
By-products of factories, etc.				
Beet pulp, dried	91.8	4.6	0.7	75.87
Beet pulp, molasses	92.4	5.9	3.5	76.28
Beet pulp, wet	9.3	0.5	0.5	8.99
Brewers' grains, dried	92.5	21.5	20.2	53.38
Brewers' grains, wet	24.1	4.6	4.4	14.53
Buckwheat bran	88.8	10.5	9.1	30.59
Buckwheat hulls	89.7	0.4	....	–7.69
Cocoanut meal, old process	90.4	18.8	18.3	83.49
Corn germ meal	91.1	16.5	14.3	83.88
Cottonseed meal, choice	92.5	37.0	35.4	93.46
Cottonseed meal, prime	92.2	33.4	32.0	90.00
Cottonseed hulls	90.3	0.3	....	9.92
Distillers' grains, dried, from corn	93.4	22.4	18.3	85.08
Distillers' grains, dried, from rye	92.8	13.6	11.1	56.01
Gluten feed	91.3	21.6	20.1	80.72
Gluten meal	90.9	30.2	28.1	84.15
Hominy feed	89.9	7.0	6.5	88.78
Linseed meal, old process	90.9	30.2	28.5	88.91
Malt sprouts	92.4	20.3	12.5	72.72

TABLE VI. Net energy values per 100 lbs. of various feeding stuffs—*continued.*

	Dry matter	Digestible		Net energy value
		Crude protein	True protein	
CONCENTRATES—continued	Lbs.	Lbs.	Lbs.	Therms
By-products of factories, etc.—cont.				
Molasses, beet	74.7	1.1	0.0	57.10
Molasses, cane, or blackstrap	74.2	1.0	0.0	55.38
Peanut cake, from hulled nuts	89.3	42.8	41.4	93.55
Peanut cake, from unhulled nuts	94.4	20.2	19.5	42.57
Red dog flour	88.9	14.8	13.2	78.80
Rice bran, high grade	89.9	7.9	7.0	45.29
Rice polish	90.0	8.0	7.1	77.70
Soybean oil meal	88.2	38.1	37.3	99.65
Wheat bran	89.9	12.5	10.8	53.00
Wheat middlings, flour	89.3	15.7	14.0	75.02
Wheat middlings, standard (shorts)	89.6	13.4	12.0	59.10
Animal products				
Buttermilk	9.4	3.4	3.4	13.32
Cow's milk	13.6	3.3	3.3	29.01
Dried blood	90.3	69.1	68.6	68.12
Skim milk, centrifugal	9.9	3.6	3.6	14.31
Tankage, over 60% protein	92.6	58.7	55.6	93.04
Tankage, 55–60% protein	92.5	54.0	51.1	83.58
Tankage, 45–55% protein	92.5	48.1	45.5	72.96
Whey	6.6	0.8	0.8	10.39
DRIED ROUGHAGE				
Hay and cured forage from grasses and cereals				
Brome hay	91.5	5.0	3.5	40.83
Corn fodder, medium in water	81.7	3.0	2.3	43.94
Corn stover, medium in water	81.0	2.1	1.6	31.62
Kafir fodder, high in water	71.7	3.0	1.8	34.28
Kafir stover, high in water	72.7	1.3	1.0	27.65
Millet hay, Hungarian	85.7	5.0	3.9	46.96
Oat hay	88.0	4.5	3.9	32.25
Prairie hay, western	93.5	4.0	2.9	40.42
Red top hay	90.2	4.6	3.9	51.22
Sorghum fodder	80.0	2.5	1.5	32.20
Timothy hay, all analyses	88.4	3.0	2.2	43.02
Timothy hay, before bloom	92.8	4.7	2.9	43.52
Timothy hay, early to full bloom	87.2	3.6	2.5	47.40
Timothy hay, late bloom to early seed	85.1	2.4	1.8	37.54
Hay from the legumes				
Alfalfa, all analyses	91.4	10.6	7.1	34.23
Alfalfa, before bloom	93.8	15.4	10.3	36.23
Alfalfa, in bloom	92.5	10.5	6.7	32.33
Alfalfa, in seed	89.6	8.5	6.2	32.23
Clover, alsike	87.7	7.9	5.3	34.42
Clover, crimson, or scarlet	89.4	9.7	6.9	36.21
Clover, red, all analyses	87.1	7.6	4.9	38.68
Clover, red, in bloom	86.1	8.1	5.3	39.12
Clover and timothy	87.8	5.3	3.6	40.85
Clover, sweet, white	91.4	10.9	6.7	38.98
Cowpea	90.3	13.1	9.2	37.59
Soybean hay	91.4	11.7	8.8	44.03
Straw and chaff				
Barley straw	85.8	0.9	0.6	36.61
Buckwheat straw	90.1	4.2	3.2	4.55
Oat straw	88.5	1.0	0.8	34.81
Rice straw	92.5	0.9	0.4	23.63
Rye straw	92.9	0.7	0.5	17.59
Wheat straw	91.6	0.7	0.3	7.22

TABLE VI. Net energy values per 100 lbs. of various feeding stuffs—*continued.*

	Dry matter	Digestible		Net energy value
		Crude protein	True protein	
FRESH GREEN ROUGHAGE	Lbs.	Lbs.	Lbs.	Therms
Green forage from grasses and cereals				
Barley fodder	23.2	2.3	2.0	14.08
Bluegrass, Kentucky, before heading	23.8	3.7	2.8	14.82
Bluegrass, Kentucky, headed out	36.4	2.8	2.2	17.77
Bluegrass, Kentucky, after bloom	43.6	1.9	1.6	21.01
Buckwheat, Japanese	36.6	2.2	1.5	17.78
Corn fodder, dent, all analyses	23.1	1.0	0.8	14.60
Corn fodder, dent, in tassel	14.9	1.1	0.8	9.52
Corn fodder, dent, in milk	19.9	1.0	0.8	13.64
Corn fodder, dent, dough to glazing	25.1	1.3	1.0	17.35
Corn fodder, dent, kernels glazed	26.2	1.1	0.8	16.74
Corn fodder, dent, kernels ripe	34.8	1.5	1.1	22.48
Corn fodder, flint, all analyses	20.7	1.0	0.8	13.53
Sweet corn fodder, roasting ears or later	20.3	1.2	0.9	13.38
Corn fodder, sweet, ears removed	21.5	1.0	0.8	14.26
Millet, Hungarian	27.6	1.9	1.1	17.24
Oat fodder	26.1	2.3	2.0	14.06
Orchard grass	29.2	1.7	1.1	15.81
Rye fodder	21.3	2.1	1.4	15.99
Sweet sorghum fodder	24.9	0.7	0.4	15.37
Timothy, before bloom	24.2	1.8	1.1	18.36
Timothy, in bloom	32.1	1.3	0.8	18.89
Timothy, in seed	46.4	1.5	1.0	26.36
Wheat fodder	27.4	2.8	1.9	18.75
Green legumes				
Alfalfa, before bloom	19.9	3.5	1.9	9.20
Alfalfa, in bloom	25.9	3.3	1.8	11.50
Alfalfa, after bloom	29.8	2.1	1.3	11.10
Clover, alsike	24.3	2.7	1.5	14.56
Clover, crimson	17.4	2.3	1.6	10.83
Clover, red, all analyses	26.2	2.7	1.7	15.87
Clover, red, in bloom	27.5	2.7	1.8	16.74
Cowpeas	16.3	2.3	1.7	10.42
Peas, Canada field	16.6	2.9	2.1	9.78
Soybeans, all analyses	23.6	3.2	2.4	12.53
Vetch, hairy	18.1	3.5	2.4	11.95
Roots, tubers, and fruits				
Apple	18.2	0.4	0.1	15.92
Beet, common	13.0	0.9	0.1	7.84
Beet, sugar	16.4	1.2	0.4	11.20
Carrot	11.7	0.9	0.5	9.21
Mangel	9.4	0.8	0.1	5.68
Potato	21.2	1.1	0.1	18.27
Pumpkin, field	8.3	1.1	0.6	6.05
Rutabaga	10.9	1.0	0.3	8.46
Turnip	9.5	1.0	0.4	6.16
SILAGE				
Clover	27.8	1.3	0.8	7.26
Corn, well matured	26.3	1.1	0.6	15.90
Corn, immature	21.0	1.0	0.4	11.96
Corn, from field-cured stover	19.6	0.5	0.3	8.98
Cowpea	22.0	1.8	1.1	11.05
Soybean	27.1	2.6	1.5	11.59
Sugar beet pulp	10.0	0.8	0.5	9.32

Table VII. Mineral Matter in 1,000 Lbs. of Representative Feeding Stuffs

The data presented in the following table have been compiled from analyses by the American Experiment Stations, especially the analyses reported by Forbes in *Ohio Bulletin 255*, supplemented by others from German sources.

Feeding stuff	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Sulfuric acid SO_3	Phosphoric acid P_2O_5	Silica SiO_2	Chlorin Cl
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn	4.0	0.4	0.2	1.8	0.11	3.8	6.9	0.3	0.65
Gluten feed	2.3	5.7	3.5	3.6	....	14.6	6.2	....	0.90
Wheat	5.3	1.6	0.6	2.2	0.23	5.4	8.6	0.4	0.82
Wheat flour	1.0	1.5	0.3	0.3	....	3.6	2.0	....	0.70
Red dog flour	7.6	...	1.7	4.8	....	6.5	20.0	....	1.40
Stand. wheat middlings	11.8	1.4	0.8	5.4	....	5.8	21.1	....	....
Wheat bran	16.2	2.4	0.9	7.3	0.34	6.7	29.5	0.3	0.90
Oats	5.6	2.3	1.4	2.0	0.38	4.9	8.1	12.5	0.70
Malt sprouts	18.3	1.1	2.1	3.0	0.95	20.0	16.5	13.5	3.60
Brewers' grains, dried	0.9	3.5	2.2	2.6	0.39	9.7	9.9	12.3	0.58
Rough rice	2.6	1.0	0.2	1.2	0.31	....	4.9	41.6	0.02
Polished rice	0.6	0.4	0.1	0.4	....	2.6	1.7	....	0.36
Rice polish	11.7	1.5	0.4	10.9	....	4.2	30.8	....	1.34
Kafir grain	3.1	0.8	0.2	2.1	....	4.1	5.7	....	1.04
Cottonseed meal	18.1	3.5	3.6	8.6	0.84	12.4	26.7	5.5	0.39
Linseed meal, old process	12.7	3.4	5.1	8.1	1.44	10.2	17.0	6.9	0.86
Bean, navy	13.7	1.0	2.8	2.9	....	4.8	7.8	....	0.40
Cowpea	14.9	2.2	1.4	3.4	....	6.0	10.1	....	0.40
Soybean	24.7	6.1	2.9	3.8	....	10.3	13.7	....	0.28
Skim milk	1.7	0.6	1.8	0.2	....	0.8	2.2	....	0.91
Whey	2.6	0.4	0.6	0.1	....	0.2	1.2	....	1.18
Beet pulp, dried	3.8	2.2	9.2	4.2	....	3.1	2.4	9.0	0.43
Distillers' grains, dried, from corn	1.7	1.9	0.6	0.8	....	11.7	6.8	....	0.60
Corn stover	12.9	6.5	6.6	1.4	0.71	4.3	4.5	9.1	2.87
Sorghum fodder	25.3	...	3.9	2.9	0.79	....	2.3	5.9	5.60
Bluegrass hay	21.0	1.7	4.3	3.6	....	7.7	5.4	....	2.15
Timothy hay	13.6	4.3	2.5	1.7	0.37	3.7	3.1	14.2	1.83
Alfalfa hay	22.3	5.6	19.5	5.9	1.68	7.8	5.4	8.1	4.74
Red clover hay	16.3	1.2	16.0	4.5	0.67	4.4	3.9	1.7	2.39
Cowpea hay	41.3	2.5	25.4	16.2	....	7.9	9.6	....	1.49
Soybean hay	23.3	1.8	17.2	10.3	....	5.8	6.8	....	0.75
Wheat straw	7.4	3.0	2.9	1.0	0.26	3.8	1.3	28.4	1.98
Mangel	2.2	1.1	0.2	0.7	0.08	0.6	0.4	0.2	1.58

Table VIII. Weight of Various Concentrates

In computing rations for farm animals it is desirable to know the weight per quart, or the bulk, of the different concentrates. The following table, compiled from *Massachusetts Bulletin 136* by Smith and Perkins, *Louisiana Bulletin 114* by Halligan, and *Indiana Bulletin 141* by Jones, Haworth, Cutler, and Summers is therefore presented.

Feeding stuff	One quart weighs	One pound measures	Feeding stuff	One quart weighs	One pound measures
	Lbs.	Qts.		Lbs.	Qts.
Whole corn	1.7	0.6	Brewers' grains, dried	0.6	1.7
Corn meal	1.5	0.7	Millet, foxtail	1.6	0.6
Corn-and-cob meal	1.4	0.7	Rice polish	1.2	0.8
Hominy feed	1.1	0.9	Rice bran	0.8	1.3
Gluten feed	1.3	0.8	Buckwheat	1.4	0.7
Gluten meal	1.7	0.6	Buckwheat flour	1.6	0.6
Corn germ meal	1.4	0.7	Buckwheat middlings	0.9	1.1
Corn bran	0.5	2.0	Buckwheat bran	0.6	1.7
Wheat	1.9	0.5	Buckwheat hulls	0.5	2.0
Wheat, ground	1.7	0.6	Cotton seed	0.8	1.3
Flour wheat middlings	1.2	0.8	Cottonseed meal	1.5	0.7
Standard wheat middlings	0.8	1.3	Cottonseed hulls	0.3	3.3
Wheat bran	0.5	2.0	Flax seed	1.6	0.6
Wheat feed (shorts and bran)	0.6	1.7	Linseed meal, old process	1.1	0.9
Wheat screenings	1.0	1.0	Linseed meal, new process	0.9	1.1
Rye	1.7	0.6	Flax feed	0.8	1.3
Rye meal	1.5	0.7	Flax screenings	1.1	0.9
Rye middlings	1.6	0.6	Beans, navy	1.7	0.6
Rye bran	0.8	1.3	Cowpeas	1.7	0.6
Rye feed (shorts and bran)	1.3	0.8	Peas, field	2.1	0.5
Oats	1.0	1.0	Soybeans	1.8	0.6
Oatmeal	1.7	0.6	Cocoanut meal	1.5	0.7
Oats ground	0.7	1.4	Cocoanut cake	1.3	0.8
Oat feed	0.8	1.3	Sunflower seed	1.5	0.7
Oat middlings	1.5	0.7	Beet pulp, dried	0.6	1.7
Oat hulls	0.4	2.5	Distillers' grains, dried	0.6	1.7
Barley	1.5	0.7	Molasses, cane, or blackstrap	3.0	0.3
Barley meal	1.1	0.9	Molasses feed	0.8	1.3
Malt sprouts	0.6	1.7	Alfalfa meal	0.6	1.7

Table IX. Vitamine Content of Feeding Stuffs

The existence of vitamines in foods was discovered so recently that investigators have as yet determined the vitamine content of but few foods or feeding stuffs. In many cases the data are yet incomplete for the feeds thus far studied, and only tentative conclusions are warranted. This table is therefore presented to indicate roughly, so far as the present information warrants, the relative values of various feeds as sources of the fat-soluble vitamine (also called vitamine A); of the water-soluble vitamine (or vitamine B); and of the anti-scorbutic vitamine (or vitamine C). Because of the general interest in these matters, data are also given for a few human foods.

The relative amounts of the different vitamines in each feed are indicated by the following symbols:

— indicates that the feed contains none of the vitamine or only a very small amount.
+ indicates that the feed contains a small amount of the vitamine.
+ + indicates that the feed is a good source of the vitamine.
+ + + indicates that the feed is an excellent source of the vitamine.
+ + + + indicates that the feed is exceptionally rich in the vitamine.
? indicates that there is no information on the vitamine content of the feed, or that the data are not conclusive.

These symbols indicate only very roughly the relative content of a given feed in the different vitamines, and where the same symbol is used to indicate the vitamine content of two foods, one of the foods may contain materially larger amounts than the other. Thus the same symbol is used to indicate the amount of fat-soluble vitamine in butter and in whole milk. This is done even tho butter is ordinarily much richer than whole milk in the vitamine, because the vitamine is concentrated in the butter fat.

This table has been prepared with the aid of Prof. H. Steenbock of the University of Wisconsin and the data have been taken from a variety of sources, including the summary presented in Report No. 38 of the British Medical Research Committee, that given by Rose in *Laboratory Handbook for Dietetics*, the summary presented by Ellis and Macleod in *Vital Factors of Foods*, and data secured by Prof. Steenbock and colleagues at the University of Wisconsin.

	Fat-soluble vitamine (Vitamine A)	Water-soluble vitamine (Vitamine B)	Anti-scorbutic vitamine (Vitamine C)
Grains and seeds			
Barley	—	+ +	—
Beans	—	+ +	—
Corn, white	—	+ +	—
Corn, yellow	+ +	+ +	—
Millet	— to + +	+ +	?
Oats	—	+ +	—
Oats, green sprouted	+	+ +	+
Peanuts	+	+ +	—
Peas	— to +	+ +	—
Rice, whole grain	—	+ +	—
Rye	—	+ +	—
Soybeans	+	+ +	—
Wheat	—	+ +	—
By-products of grains and seeds			
Cocoanut oil	—	—	—
Cottonseed oil	—	—	—
Peanut oil	—	—	—
Rice, polished	—	—	—
Starch	—	—	—
Sugar	—	—	—
Wheat bran	—	+ +	—

TABLE IX. Vitamine content of feeding stuffs—*continued.*

	Fat-soluble vitamine (Vitamine A)	Water-soluble vitamine (Vitamine B)	Anti-scorbutic vitamine (Vitamine C)
By-products of grains and seeds—cont.			
Wheat flour, patent	—	+	—
Wheat middlings	—	+ + +	—
Yeast	—	+ + + +	—
Animal products			
Butter	+ + +	—	—
Buttermilk	+	+ +	+ variable
Cod liver oil	+ + + +	—	—
Cream	+ + +	+	+ variable
Cheese	+ +	?	?
Eggs	+ +	+	?
Lard	— variable	—	—
Milk, whole	+ + +	+ +	+ variable
Skim milk	+	+ +	+ variable
Hay			
Alfalfa, well-cured, green colored	+ + +	+ +	—
Alfalfa, bleached by exposure	—	?	—
Clover, well-cured, green colored	+ + +	+ +	—
Timothy, well-cured, green colored	+ +	+	—
Green forage and silage			
Alfalfa, green	+ + +	+ +	+ + + +
Cabbage, white portion	+ +	+ +	+ + +
Cabbage, green leaves	+ + +	+ +	?
Clover, green	+ + +	+ +	+ + + +
Corn silage	+ +	?	—
Grasses, green	+ + +	+ +	+ + + +
Squash, Hubbard	+ +	?	?
Roots, tubers, and fruits			
Apples	?	+	+
Beets, red	—	— to +	— to +
Beets, sugar	—	— to +	— to +
Carrots, yellow	+ +	+ +	+ +
Carrots, white	— to +	+ +	?
Mangel	—	— to +	— to +
Orange juice	+	+	+ + + +
Potato, Irish	— to +	+ +	+ +
Rutabagas	?	+ +	+ + +
Sweet potatoes, yellow	+ +	+ +	?
Tomatoes	+ + +	+ + +	+ + +

INDEX

The References are to Pages

Abomasum, 19
Absorption of nutrients, 34–5
Acid, effect of, on digestibility of feed, 54
Acid in gastric juice, 21, 28
Acorns, 190
  effects on pork, 190
Adulteration of feeds, 191–3
Aftermath, 221
Age, influence on digestibility, 54
Age, influence on gain of pigs, 599–601; sheep, 540; steers, 448–52
Age influence on milk yield of cows, 347
Age to breed ewes, 577; heifers, 441, 520; mares, 320; sows, 701
Air required by farm animals, 69
Albumin in milk, 79, 345, 347
Alfalfa, 225–31
  compared with other forages, 226
  types of, 230
Alfalfa feed, 230
Alfalfa hay, 225–8
  cut at various stages, 51, 226
  for beef cows, 508, 510; beef calves, 517; brood sows, 686–8; dairy calves, 432; dairy cows, 375–9; dairy heifers, 439–40; ewes, 581; horses, 313–5; pigs, 680–3, 686–8; sheep, 550–2, 562–3; steers, 470–2, 487–92, 517
  ground, see Alfalfa meal
  in place of concentrates for cows, 377–9
  losses of feeding value in hay-making, 220
  making, 220–3
  stage to cut, 226, 490
  value of different cuttings, 227, 377
  yield compared with corn crop, 226
Alfalfa meal, 230
  for cows, 230, 379; horses, 315; pigs, 682–3; sheep, 544
Alfalfa pasture, 228
  for cows, 394; horses, 228; pigs, 664–70; sheep, 228, 574
Alfalfa silage, 230, 260
Alfalfa soilage, 229, 268
Alfalmo, 231, 306
Alimentary tract, 19
Alsike clover, see Clover, alsike
Amids, 7
  digestion of, 29
  in corn crop, 13
  in various feeds, 4
  use by animals, 63–4
Amino acids, 8, 28
  absorption of, from intestine, 35
Amylase, or amylopsin, 24
Anabolism, 33
Animal, as a machine, 105–6
  composition of, 15–8
Animals, checking growth of, 97–100
  nutrients stored by young, 77
Animals and plants compared, 17
Apples, 249
  for pigs, 250
Apple pomace, 249
Apple pomace silage, 260
  for cows, 389
Armsby's net energy values for feeds, 46–50, 121–3, Appendix Table VI
Armsby's feeding standards, 121–8
Artichokes, 246
  for horses, 316; pigs, 678
Ash, see Mineral matter
Ashes, wood, for pigs, 604–5
Assimilation of food, energy lost in, 46–8
Available energy, 45

Baby beef, 532–4
Bacon hogs, 618–20
  see Pigs
Bacon production, 621–2
Bacteria, action in digestion, 23, 28
Bagasse, sorghum, for silage, 205, 260
Balanced ration, 18
  see Ration
Barley, 163
  for calves, 426; cows, 365; horses, 304; pigs, 632–4; sheep, 554; steers, 474
  see Cereals
Barley and by-products in brewing, 164–6
Barley bran, 166
Barley feed, 166
Barley hay, 212, 310
Barley pasture and soilage, 212
Barley straw, 218
Barrows and sows, gains of, 620
Beans, castor, 255
Beans, field, 182
  for horses, 309; pigs, 659; sheep, 182
Beans, horse, see Horse bean
Beans, hyacinth, 24
Beans, moth, 240
Beans, table, see Beans, field
Beans, velvet, see Velvet bean
Bean straw, 218, 564
Beef, baby, 532–4
  cost of producing, 534
Beef calves, see Calves, beef
Beef cattle, 445–536
  fattening calves, 450–2, 532–4; yearlings, 450–2, 534; 2-yr.-olds, 450–2, 535
  raising, 507–20
  summer care of, 507, 516
  wintering, 508–13, 516–9
  see Steers
Beef cows, see Cows, beef
Beef production, 445–536
  cost of, 511—3, 534, 535–6
  methods of, 527–35
Beet, mangel, see Mangel
  sugar, see Sugar beet
Beet leaves, see Beet tops and leaves
Beet molasses, see Molasses, beet
Beet pulp, dried, 187
  for cows, 366; horses, 306; sheep, 558; steers, 479
Beet pulp, molasses, 188
  for cows, 367; sheep, 558
Beet pulp, wet, 186
  for cows, 392; horses, 317; pigs, 677; sheep, 572; steers, 477–8
Beet pulp silage, 187, 260
Beet tops and leaves, 188
  for steers, 478
  silage from, 188, 478
Beggar weed, 240
Bermuda grass, 213
Bermuda hay for cows, 383; horses, 311
Big neck, see Goitre

Bile, 25
Blanketing horses, 298
Bloat, in ruminants, cause of, 23;
how prevented, 228, 234, 573
Blood, circulation of, 33
Blood meal, or dried blood, 186
for calves, 427; cows, 375; horses, 309; pigs, 652; sheep, 561
Blood of pigs, influence of corn feeding on, 93–4
Bluegrass, Canada, 213
Bluegrass, Kentucky, 207
Bluegrass pasture for dairy cows, 393; horses, 315; pigs, 674; sheep, 573, 576; steers, 527–32
Bluegrass hay for sheep, 565
Blue joint grass, 216
Boar, feed and care of, 693
Body temperature of farm animals, 56–9
Body waste, disposal of, 29, 36
Bonavist, 241
Bone, increase of, in young animals, 76–77, 84
Bone ash for farm animals, 68; pigs, 83
Bone meal, 68, 83, 186
for calves, 428; cows, 362; foals, 325 pigs, 602–5
Bones, weak because of lack of calcium 66,82,93–6
Bran, see Wheat bran, Rice bran, etc.
Bran disease, 160
Bread, 159, 272
for horses, 159, 272
Breed, influence of, on digestibility, 54
Breed, value in beef production, 459–65
Breed tests of cows, 415–6; sheep, 539; steers, 460, 465; swine, 619
Brewers' grains, dried, 165; for cows, 369; horses, 308; pigs, 165; sheep, 561; steers, 486
pentosans in, 165
Brewers' grains, wet, 165
Brome grass, 210
Brome hay for horses, 311
Brood mare, see Mare, brood
Brood sow, see Sow
Broom-corn seed, 172
Buckwheat, 173
effects on butter and pork, 173
for pigs, 639
Buckwheat bran, value of, 173
Buckwheat hulls, feeding value, 173
Buckwheat middlings, feeding value, 173
for cows, 369; pigs, 664
Buckwheat straw, 219
Bull, beef, feed and care of, 513
Bull, dairy, feed and care of, 442–4
Butter, effects of buckwheat on, 173; cocoanut meal on, 181, 373; cottonseed meal on, 176, 369; linseed meal on, 372; potatoes on, 392; soybeans on, 180, 372
yellow color of, caused by carotin 356
Buttermilk, 184
for calves, 434; pigs, 642; 644–8
Buttermilk, dried, 184, 648
Buttermilk, semi-solid, 184, 647–8

Cabbage, 247
Cacti, 251–2
for cows, 252; steers, 251–2
spineless, 252
Caecum, 20, 26
Calcium, 3, 17, 64–8
effect of deficiency in ration, 66–7
feeds low in, and rich in 66–7, Appendix Table VII
in blood, 64
in legumes, 66
in skeleton, 17, 64
required for growth, 82–3
required for maintenance, 66–7
see Mineral matter
Calcium carbonate utilized by animals, 67–8
Calcium phosphate, for farm animals, 67–8; pigs, 82–3
Calf meals, 436–7
Calorie, 45
Calorimeter, 45
respiration, 44
Calves, beef, 507–8, 511–3, 514–20
feed and care of, 516–20
wide and narrow rations for, 96
wintering, 516–20
Calves, dairy, 423–42
(For the value of the various feeds for calves, see the different feeds; i. e., Corn, Oats, etc.)
advantage of fall-dropped, 438
birth weight, 438
calf meals for, 436–7
concentrates for, 425–8, 431
cost of rearing, 441–2
fall vs. spring, 438
feeding concentrates only, 432
gains made by, 433
grinding grain for, 426
growth of, 433
hay for, 432
mineral matter, requirements of, 423, 428
nutrients required by, 423
percentage of food nutrients stored by, 77
precautions in rearing, 437
protein requirements of, 424
raising on minimum amount of milk, 434–5; skim milk, 429–31; skim milk substitutes, 434, 436–7
returns from, compared with other farm animals, 90–2
rich and poor milk for, 79
salt for, 428
scours, 438
succulent feeds for, 432
variety of feeds, effect of, 427
vitamine requirements of, 423
water for, 428
Canada field pea, see Pea, field
Cane molasses, see Molassess, cane
Cane sugar, 4–5
Capillaries, 33
Carbohydrates, 4, 40
absorption of, 34
a source of muscular energy, 101–3
determination in feeding stuffs, 11
digestion of, 26
effect on digestibility of nutrients, 53
energy lost in digesting, 47–8
fat formed from, 87
formation in plants, 4
in animal body, 16
in ripening clover, 233; corn, 12–14; grasses, 206
what the term embraces, 40
Carbonaceous feeds, 42
Carbon dioxid, 2
amount in air, 2
danger from, in silo filling, 264
produced by horse during work, 102
the great food of plants, 2
Carbonic acid gas, see Carbon dioxid
Carcass, see Dressed carcass
Carob beans, 182
for calves, 427
Carotin causes color of butter, 356
Carpet grass, 215
Carrots, 245
for horses, 316
Casein in milk, 183, 345
Cassava, 247
for pigs, 680; steers, 505
Castor bean, 255
Catabolism, 33
Cattle, see Cows, Steers, Beef production
Cellulose, 4–5
digestion of, 23, 27
nutritive value of, 23
Cereal hay, 212
for horses, 310

Cereal pasture, 212
for cows, 212; pigs, 674; sheep, 574
Cereal silage and soilage, 212
Cereals, 151–73
Chaff from the cereals, 218
Chaffing hay or straw, see Chopping hay
Chalk for farm animals, 68, 83
Charcoal for pigs, 604
Chopping hay and straw, 270
for horses, 296; sheep, 544
Chlorophyll, function of, in plants, 4
Christmas lambs, see Hot-house lambs
Chufas, 247
for pigs, 680
Chyle, 34
Circulative canals of body, 33–4
Climate, influence of, on composition of feeds, 50
Clipping horses, 298
Clover, 231–7
alsike, 234
bloat from, how prevented, 234
bur, 237
combined with timothy, 232
crimson, 236
Japan, see Lespedeza
mammoth, 234
Mexican, 250
Clover, red, 231–4
development of nutrients in, 232
losses in curing, 220
methods of making hay from, 220–3
pasture, 234
silage, 234
for cows, 388
soilage, 234
time to cut, 233
Clover, sweet, 235
pasture, for pigs, 671
Clover, white, 235
Clover hay, alsike, 234
for sheep, 563
Clover hay, crimson, 236
dangerous to horses, 236
for cows, 380
Clover hay, Japan, see Lespedeza hay
Clover hay, red, 233
for beef cows, 508; beef calves, 517, 519; dairy calves, 432; dairy cows, 379; ewes, 581; horses, 313; pigs, 680, 683; sheep, 550–2, 562–3; sows, 686–8; steers, 470–2, 487–8, 489
Clover hay, rich in lime, 66, 83
Clover hay, sweet, for cows, 380; horses, 315; sheep, 563; steers, 492
Clover pasture for pigs, 664–9, 670; sheep, 573
Clover silage, 234, 260
for cows, 388
Coarse forage, see Roughage
Cocoanut meal or cake, 181
for cows, 373; horses, 309; pigs, 664
Cocoa shells, 191
Coefficients of digestibility, 38–40, Appendix Table II
Colic in horses, due to feed, 299, 303, 305
Colostrum, 79, 409
Colts, daily gains of, 321–3
education of, 325
see Foals
Comfrey, prickly, 250
Commercial feeds, 192–3
Common salt, see Salt
Composition of feeding stuffs, 9–12, Appendix Table I
factors influencing, 50–2
Concentrates, 12
adapting amount fed to local conditions, 148
compared with roughages, 48
feeding animals exclusively on, 74
proper amount for dairy cows, 395–401; horses, 330-2; pigs, 610–6; sheep, 592; steers, 455–9, 473, 501
Cooked feed, 271
digestibility of, 53, 271
for dairy cows, 404; pigs, 271, 609–10; horses, 296
Corn, Indian, 151–5, 195–203
by-products of, 155–7
composition of, 154
dent, characteristics of, 152
ear, for cows, 364; horses, 303; pigs, 607–9, 626; sheep, 552–3; steers, 473–4
ear, shrinkage in drying, 153
effects of thick planting on, 196
feeding exclusively to pigs, 92–6
field feeding to pigs, 628–30; sheep, 593
flint, characteristics of, 152
for calves, 426; cows, 363–4; horses, 302–4; pigs, 623–30; sheep, 550–3; steers, 470–4
grades of, 153
grinding, see Corn, preparation of
heavy vs. light feeding to pigs, 610–6; sheep, 592; steers, 455–9, 473, 501
hogging down, 628–30
lacks protein and mineral matter, 92–6, 152
lambing down, 593
loses palatability after grinding, 155
preparation of, for calves, 426; cows, 364; horses, 303; pigs, 607–9; sheep, 552–3; steers, 473–4
races of, 152
shelled, for calves, 426; horses, 303; pigs, 607–9; sheep, 552–3; steers, 470–4
soaked, for pigs, 608–10; steers, 473
soft, 154
for pigs, 628; steers, 474
sweet, characteristics of, 152
water in green and dry, 153
weight per bushel, 153
yellow compared with white, 152
yellow, low in fat-soluble vitamine, 72, 152
yellow versus white for swine, 626–8
see Corn crop and Corn plant
Corn-and-cob meal, 155
for cows, 364; horses, 303; pigs, 628; sheep, 552–3; steers, 473–4
Corn bran, 157
Corn chop, see Corn meal
Corn cobs, weight and composition of, 153
Corn crop, changes in composition during ripening, 12–4
distribution of nutrients in ears and stover, 197
losses in field curing, 198
proportion of ears and stover, 197
yield of nutrients in 1 acre, 12–4
Corn feed-meal, 155, 628
Corn fodder, 195, 198–9, 201–2
for cows, 382, 385; horses, 311; sheep, 565; steers, 492, 501
green, for soilage, 202
pulling fodder, 202
shocking or stooking, 198, 201
shredding, 202
versus corn silage for cows, 385–6 steers, 501
Corn fodder silage, 200
Corn forage, see Corn fodder and Corn stover
Corn germ meal, 157
for cows, 368; pigs, 662
Corn gluten feed, see Gluten feed
Corn gluten meal, see Gluten meal
Corn kernel, parts and composition, 154
Corn meal, 155
for calves, 426; cows, 364; horses, 303; pigs, 607–9; sheep, 552; steers, 473–4
Corn oil cake meal, see Corn germ meal
Corn plant, 12
distribution of nutrients, 197

Corn plant, *continued*
losses by ensiling and field curing, 198
number of stalks per acre, 196
nutrients at different stages, 12
removing ears before ensiling, 200–1
Corn silage, see Silage, corn
Corn smut, feeding experiments with, 254
Corn soilage, 202
Corn stalk disease, 254
Corn stover, 195, 202
for beef cows, 510; dairy cows, 382; horses, 311, 312; sheep, 565; steers, 492
shredded, 202
Corn stover silage, 200, 387, 501, 510
for beef cows, 510; dairy cows, 387; steers, 501–2
Cost of feeds, considering in computing rations, 116, 140–7
Cotton seed, 173–4
for cows, 371; steers, 483
poison in, 175
products from 1 ton, 173
Cottonseed cake, see Cottonseed meal
Cottonseed cake, cold-pressed, 175
for cows, 371; sheep, 560; steers, 483
Cottonseed feed, 175
for steers, 483
Cottonseed hulls, 177
for cows, 384; steers, 494
Cottonseed meal, 174–7
effects on animal fats, 176
for beef cows, 509–11; calves, 175; dairy cows, 369–71; horses, 308; pigs, 175, 658; sheep, 559; steers, 481–3, 497–9, 518, 519
poison in, 175
Cowpea hay, 237
for cows, 380; horses, 315; sheep, 563; steers, 492
Cowpea pasture, 237
for pigs, 673
Cowpea silage, 237, 260
for cows, 389; steers, 504
Cowpeas, 182, 237
for pigs, 660; horses, 309; steers, 485
Cows, beef, 507–13
cost of keeping, 511–3
feed and care of, 507–13
feed requirements of, 507–8
mineral matter for, 508
versus dairy cows for milk production, 339
wintering, 508–13
Cows, dairy, 337–422
(For the value of various feeds for cows, see the different feeds; i. e., Corn, Clover hay, etc.)
advanced registry, 344
annual feed requirements, 410–5
as producers of human food, 337–8
breed tests, 415–6
building a good herd from scrubs, 340
bulkiness of concentrate mixture for, 397
calculating rations for, 114–8, 140–7, 396, 397–402
calving time, 408
care before and after calving, 407–9
censuses of production, 343
comfort, importance of, 403
concentrate allowance for, 357, 395–402
concentrates for, 363–75, 397–402
cooking feed for, 404
cost of milk production, 410–5
dairy vs. beef type, 339
dehorning, 355
dry, feed for, 407
drying off, 407
economy of, 337–8
effects on milk yield of advancing lactation, 348; age, 347; cattle ticks, 355; condition at calving, 349; dehorning, 355; exercise, 354; feed, 349–52; frequency of milking, 355; grooming, 354; milking machines, 354; oestrum, 355; pregnancy, 355; temperature and weather, 353; tuberculin testing, 355; turning to pasture, 353
exercise for, 354, 404
feed and care of, 395–409
feed and care of test cows, 416–22
feed required by, for 1 year, 410–5
feeding as individuals, 396
feeding exclusively on concentrates, 74
feeding on pasture, 406–7
feeds for, 363–94
frequency of feeding, 404
frequency of milking, 355
freshening in fall vs. spring, 409
gestation period, 408
good and poor producers, 339–44
great, feed and yield of, 421–2
grinding grain for, 270, 364, 404
grooming, 354
Hegelund method of milking, 405
inefficient, causes of, 341
kindness in care of, 405
liberal and meager feeding, 349–51, 363–4, 395
lime withheld from, 66, 361
milk, see Milk, cow's
milk and fat records, 344
milking machines, 354
mineral matter requirements of, 361–2
nutrients required by, 108–10, 357–62
official tests, 344
order of feeding, 404
overfeeding, 352
palatable feed, importance of, 397
pasture, supplementing short, 406–7
pasturage vs. soilage for, 392–3
preparation of feed for, 404
profitable and unprofitable, 339–42
protein requirements of, 359–61
ration for, should be well balanced, 357–62, 395
rations for, examples of economical, 140–7, 397–402
rations when on test, 416–22
records, keeping on farm, 342
records of great cows, 344, 421–2
regularity in care of, 405
rest for, importance of, 407
returns from, compared with other farm animals, 90–92, 337–8
returns from, in Swedish test associations, 130
returns from good and poor producers, 339–41
roughages for, 375–94
salt for, 403
shelter for, 403
soaking feed for, 404
substituting legume hay for concentrates, 377–9
succulent feed, importance of, 384, 397
succulent feeds for, 384–94
test cows, feed and care of, 416–22
tests of, at expositions, 415–6
tests, official, 344, 416–22
tests, unreliability of short, 342
tuberculin testing, 355
turning to pasture, 353
underfeeding, effect of, 349–351, 352
use of feed by, 338
variations in fat in milk, 345–54
vitamine requirements of, 357
water for, 402
see Heifer
Cows, dual-purpose, feeding, 513
Cow-testing associations, 344
Crab grass, 215
Creep for calves, 532; foals, 323; lambs, 588; pigs, 699

Crimson clover, see Clover, crimson
Crude protein, see Protein, crude
Crushing grain, see Grinding grain
Cud, chewing the, 20
Cull beans, see Beans
Cutting hay and straw, see Chopping hay and straw

Dairy versus beef breeds for beef production, 460–2
Dairy by-products, see Skim milk; Buttermilk; Whey
Dairy calves, see Calves, dairy
Dairy cows, see Cows, dairy
Dairying, see Cows, dairy
Darkness, see Light
Darso, 172
  for pigs, 639
Dehorning, effects on cows, 353
Diastase, 165
Digestibility, 37–43
  coefficients of, 38–40, Appendix Table II
  depression of, 53–4
  effect of acid on, 54
  factors influencing, 52–5
  general discussion of, 37–43, 50–5
  influence of age, 54; amount of feed eaten, 52; breed, 54; frequency of feeding, 53; kind or class of animal, 54; palatability of feed, 30–1; preparation of feed, 52, 270–2, 609; proportion of different nutrients, 53; water, 53; work, 53
  method of determining, 37–8
  of cooked food, 53, 271
  of food by horse, 54, 285; pig, 54; ruminants, 54
  of grasses affected by maturity, 51
  of ground grain, 52
  of silage, 53
Digestible nutrient, 18
Digestible nutrients in feeding stuffs, 40–1, Appendix Table III
Digestion, 18–32
  heat evolved in, 45–50
  in caecum of horse, 26
  in intestines, 23–5
  in mouth, 21
  in stomach, 21–3
  studies of Pawlow on, 30–1
  work involved in, 45–50
Digestion coefficients, 38–40, Appendix Table II
Digestion trials, 37–8
  limitations of, 42
Digestive tract of farm animals, 19
Dipping sheep, 591
Distillers' grains, dried, 190
  for cows, 374; horses, 309; pigs, 664; sheep, 561; steers, 486
Distillery slop, 190
  for pigs, 664; steers, 486
Draft, energy expended by horses in, 289
Draft, required on different road beds, 285
Dressed carcass, composition of, from farm animals, 16
Dressed carcass yielded by pigs, 620; sheep, 548; steers, 461
Dried beet pulp, see Beet pulp, dried
Dried blood, see Blood meal
Dried brewers' grains, see Brewers' grains, dried
Dried distillers' grains, see Distillers' grains, dried
Dried fish, see Fish meal
Durra, 170, 171

Earth nut, see Peanut
Economy in feeding live stock, 140–50
Economy of animal production, 90–2
Egyptian corn, see Milo
Emmer, 167
  for cows, 366; pigs, 636; sheep, 557; steers, 477
Energy, 43–50
  available and net, of feeds, 45–50
  for animals derived from sun, 9
  for work, source of, 101–3
  gross energy of feeds, 44–5
  in pure nutrients, 45
  muscular, production of, 101–6
  net, 46
  of feeds, losses of, in digestion, 45–50
  required for growth, 77; fattening, 89, 448, 592, 610–6; maintenance, 59; milk production, 108, 357; work, 104, 290–1
  required for work, factors influencing, 104, 288–90, 292
  see Work
Energy values of feeds, Armsby's, 121–3, Appendix Table VI
Engine compared with animals, 44, 45, 105–6
Ensilage, see Silage
Ensiling, manner in which green forage is preserved by, 256
Enzymes, 21
Erepsin, 25
Ergot, 253
Ether extract, see Fat
Ewes, breeding, 577–87
  concentrates for, 580
  cost of keeping, 582–3
  feed and care before and after lambing, 583–4
  feed and care of, 577–87
  flushing, 578
  gestation period, 577
  lambing time, 583
  milking qualities, 585–6
  roughages for, 581–2
  succulent feeds for, 581–2
Ewe's milk, composition of, 78, 585
Excrement, see Manure
Exercise for brood sows, 618, 692; carriage horses, 298, 334; dairy cows, 404; ewes, 579; horses, 298; lambs, 543, 595; pigs, 618; stallions, 328; steers, 468
  importance of, 75
Exposure for lambs, 542; steers, 466–7

Farm animals, see Horses, Cows, dairy, etc.
  calculating rations for, 118–20, 126–7, 137–9, 140–7
  comparative fattening qualities of, 90–2
  composition of bodies of, 15–8
  importance of, to agriculture, vii–x
  relative economy of, 90–2, 337–8, 450, 599–600
  see Live stock
Farming, adapt type of, to local conditions, 147–50
Farm manure, see Manure
Fat, 6, 11, 15, 16
  absorption of, 34
  a source of muscular energy, 102
  digestion of, 26
  effect of cottonseed meal on, 176
  feeding, effect on digestibility, 54
  feeding to calves, 426; dairy cows, 351
  formed from carbohydrates, 87; protein, 88
  globules in milk, 346
  in animal body, 15, 16
  in milk, factors influencing composition and yield, 346–55
  in plants, 6, 11
  origin in body, 86–8
  source of, in milk, 107
  wool, 110
Fatten animals to meet demands of market, 148
Fattening, 84–97
  composition of increase during, 84–6
  factors influencing, 89–90
  object of, 84
  ration for, 88
Fattening period, length for pigs, 599–601; sheep, 592; steers, 452–5

Fattening qualities of ox, sheep, and pig compared, 90–2
Fatty tissues, storage of, see Fattening
Feces, 29, 36
energy lost in, 45–8
Feed, consumed by various classes of animals, see Horses, Cows, etc.
cooking, for farm animals, 271–2; dairy cows, 404; horses, 296; pigs, 609
preparation for farm animals, 269–72; calves, 426; cows, 364, 404; horses, 296–7; pigs, 607–10; sheep, 543–4; steers, 468, 473–4
regulation of sale, 192
returns from, by various farm animals, 90–2
soaking, 272
for dairy cows, 404; horses, 296; pigs, 607–10
waste, utilized by live stock, viii
see Feeds, also Feeding stuffs
Feed adulteration, 191–3
Feeding standards, 112–39
for dairy cows, comparison of, 133
for dairy cows, Eckles', 133; Haecker's, 131–3; Savage's, 133
Scandinavian, 131
Woll-Humphrey, 132
for farm animals, 112–39
Armsby, 121–8
Kellner, 120–1
Morrison, 134–9, 140–7, Appendix Table V
Wolff, 112
Wolff-Lehmann, 113–4, 118–20, Appendix Table IV
for lambs, Bull-Emmett, 125
history of, 112–3
only approximate guides, 117
Feeding stuffs, 151–272
adulteration, 191–3
carbonaceous, 42
coefficients of digestibility, 38–40, Appendix Table II
composition, 9–12, Appendix Table I
factors influencing, 50–2
control, 192–3
cost of, considering in computing rations, 140–7
digestible nutrients in, 40, Appendix Table III
fertilizing constituents in, 275–7, Appendix Table III
for various classes of animals, see Horses, Cows, dairy, etc.
guide in purchasing, 192
market prices not guide to value of, 140
measuring usefulness of, 37–55
mineral matter in, 8, 10, 66–7, Appendix Table VII
mixed or proprietary, 191
net energy values of, Armsby's, 121–3, 127–8, Appendix Table VI
selecting for economical rations, 140–7
starch values, Kellner's, 120–1
true value of, for work horses, 286
variations in composition, 50–2
see Feed
Feeds, see Feeding stuffs, also Feed
Feed units, 128–31
Fertility, buying, in purchased feeds, 277
selling, in crops, 277
Fertilizers, essential elements in, 273
see Manure
Fertilizing constituents in feeding stuffs, 275–7, Appendix Table III
Fertilizing value of feeds, retained and voided by animals, 274
Fertilizing value of feeds, British system of compensation for, 278
Fermentation in paunch, 23
Feterita, 170, 171
for pigs, 638; sheep, 558; steers, 476–7
Feterita fodder, 203
Fiber, 6
digestion of, 23, 27
how determined in feeds, 11
loss of energy in digesting, 48–50
Field bean, see Bean, field
Field pea, see Pea, field
Filly, weight of, at birth, 321
time to breed, 320
Fish meal, 186
for dairy cows, 375; pigs, 652
Flat turnips, see Turnips
Flavor of milk affected by feed, 355
Flax feed, 179
Flax oil-feed, 179
Flax plant by-product, 179
Flax seed, 177
for calves, 427
Flax straw, 219
Flesh formation, 76
Flesh meal for dairy cows, 375; sheep, 561
Flock, see Sheep
Fleur, manufacture of, 158
Flour, red dog, 160
Flour wheat middlings, see Wheat middlings
Foaling time, care of mare at, 320
Foals, care of, 321–8
cost of raising, 327–8
creep for, 323
feed for, 323–8
fall, 321
forcing draft, 325–8
gains of, 321–3
mineral matter for, 325
raising orphan, 324
weaning, 324
weight of, at birth, 321, 322
see Colt
Fodder corn, see Corn fodder and Corn forage, etc.
Food, see Feeds, also Feeding stuffs
Forage, coarse, see Roughage
green, digestibility of, 52
Forage poisoning, 253
Force, see Work
Foot-ton and foot-pound, 284
Fowl meadow grass, 213
Fruit, 249
for horses, 316
Fruit sugar, 4, 5
Fuel value of feed, see Energy

Gains, by dairy calves, 433; foals, 321–3; lambs, 540; pigs, 599–601; sheep, 540; steers, 448–52
Gains, comparative, by various animals, 90–2
Gains of growing animals, 76–8, 84–6
Garbage for pigs, 641
Gasoline and steam engines compared with animals, 44, 45–6, 105–6
Gastric juice, 21
Germ oil meal, see Corn germ meal
Gestation period of cow, 408; ewe, 577; mare, 320; sow, 694
Glucose, 4–5
in blood and muscles, 34, 103
manufactured from corn, 155
Gluten feed, 156
for cows, 368; horses, 309; pigs, 662; sheep, 561; steers, 486
Gluten meal, 156
for cows, 368; horses, 309
Gluten of wheat, 158
Glycogen, 34, 103
stored in liver and muscles, 34, 103
Goat, Angora, 597
milk, 598
Goitre, 68
in calves, 362, 508; lambs, 546; pigs, 605
Goober, see Peanut
Grains, see Cereals, also Corn, Wheat, etc.
grinding, see Grinding grain
ground, digestibility of, 52
hogging down ripe, 675

Grains, *continued*
preparation of, see Feeding stuffs, preparation of
Grass, 206–17
beef production on, 527–32
changes in ripening, 206
curing into hay, 219–224
dried compared with fresh, 219
effects of frequent cutting on yield, 207
effects of weather in curing, 220
for silage, 260
influence of stage of maturity upon, 50–2, 206
pasture for pigs, 674
time to cut for hay, 207, 208
Grasses, mixed, 216
the smaller, 206–17
see Hay, also Pasture
Grazing, effect of undue, 217
Greasewood, 251
Green forage, digestibility of, 52
Grinding grain for calves, 426; cows, 404; farm animals, 270; horses, 297; pigs, 607–9; sheep, 543, 552–3; steers, 468, 473–4
Grinding hay, 270
Grooming, effects on cows, 354
Grooming horses, 299
Ground bone, see Bone meal
Ground feed, 163
Ground rock phosphate, see Phosphate, rock
Growing animals, 76–84, 90–100
effect of checking growth of, 97–100
milk natural food for young, 78
roughing through the winter, 148
Growth of animals, 76–84
increase in protein and mineral matter during, 76–9
relation between composition of milk and rate of, 79
mineral matter requirements for, 82–3
protein requirements for, 80–2
vitamine requirements for, 83
Guinea grass, 215
Gullet, 19

Haecker feeding standard for dairy cows, 131, 133
Hairlessness in pigs, etc., 68; see Goitre
Hairy vetch, see Vetch, hairy
Hay, 206–41
aids in curing, 222
aroma of, 220
brown, 223
digestibility of, 52
chaffing or cutting, see Chopping hay
changes while curing, 219–22
losses by stacking, 224
making, 219–24
measurement, 224
new made, laxative, 221
salt or lime for curing, 221
shrinkage, 224
spontaneous combustion, 223
time to cut alfalfa for, 226; clover for, 233; grass for, 207, 208
versus corn silage for dairy cows, 386
see Grasses, Legumes, Alfalfa, Clover, etc.
Hay equivalents, 112
Heat, amount in coal, pure nutrients, and various feeds, 45
energy expended in body takes form of, 46, 57
loss from body, 58–61
lost in digestion, 45–50
lost in warming water drunk, 70
production in body, 56–8
regulation in body, 58–9
requirements for maintenance, 59–61
see Energy
Heating water for farm animals, 70
Heifers, beef, 514, 516, 520
versus steers for beef production, 468
Heifers, dairy, advantage of home-reared, 423
Heifers, dairy, *continued*
age to breed, 441
cost of rearing, 441–2
feed and care of, 439–41
yield of, compared with cow, 347
Hemp seed cake, 373
Herbivora, feeding concentrates only to, 74
Herd's grass, see Timothy
Hogs, see Pigs
Hogging down corn, 628–30; ripe grain, 675
Hominy feed, 157
for cows, 364; pigs, 631; sheep, 553; steers, 480
Honeycomb, or second stomach, 19
Hordein, 7
Horse bean, 182
for horses, 309
Horse power, definition, 284
Horses, 283–336
(For value of various feeds for horses, see the different feeds; i. e., Corn, Oats, etc.)
air breathed by, 69
army, feed and care of, 335
blanketing, 298
body temperature of, 57
care of, hints on, 298–300, 319–36
carriage, feed, and care of, 334
chaffing hay for, 296
clipping, 298
compared with tractor, 105, 295
concentrates for, 301–9
cooked feed for, 296
cost of horse labor, reducing, 293
cost of keep, 317–8
cost of raising, 327–8
digestibility of food by, 26, 54, 285
effects of exercise and work on, 285
efficiency of, as motors, 105, 292–6
energy expended in carrying load, 289; in draft, 289; lifting body, 290; locomotion, 289
exercise for, 298
fattening, 333–4
feed and care of, 319–36
feed consumed yearly, 317–8
feed, preparation of, for, 269–72, 296–7
feeding, supervision of, 300
feeds for, 301-18
fitting for shows, 334
grade, effect on energy expended in work, 290
grinding grain for, 270, 297
grooming, 299
hints on feeding, 298–300
locomotion of, 289
magnitude of horse industry, 283
maintenance requirements, 287
measuring work performed by, 284
nutrients required by, 290
power exerted by, of varying weights, 284
protein requirements of, 287, 290
rations for, 290, 330–2
roughage, excess of, injurious, 310
roughage, necessity of, 74
roughages for, 310–17
saddle horse, care and feed of, 334
salt for, 297
severe work by, 292
soaking grain for, 296
speed influences energy required for work, 289
stables for, 298
succulent feeds for, 315–7
sudden changes in feed dangerous, 299
supervision of feeding, 300
teeth, care of, 299
trotting, feed and care of, 334
versus the tractor, 295
watering, 297
weight, variations in, 292
wintering, 332
work horse, feed and care of, 330–2
work performed by, 284

Horses, *continued*
work, factors, influencing, 284–96
work, types of, 288
Hothouse lambs, see Lambs, hot-house
Hungarian grass, see Millet
Hydrochloric acid in gastric juice, 21
Hydrochloric acid, influence on pancreatic secretion, 24

Increase during fattening, composition of, 84–6
Indian corn plant, see Corn
Inorganic phosphorus, see Calcium phosphate
Intestinal secretion, 25
Intestine, large, digestion in, 25
Intestine, small, digestion in, 23–5
Intestines, length and capacity of, 19, 620
Invertases, 25
Iodide, potassium, cures goitre, 69
Iodine in plants, 1
Iodine, lack of, causes goitre, 68
Iron in blood, 57, 65
Iron in plants, 3
Ivory nut meal, 191

Japan clover, see Lespedeza
Japanese millet, see Millet, Japanese
Japanese cane, 215
for pigs, 676; steers, 505
Jerusalem artichoke, see Artichoke
Johnson grass, 214
Johnson grass hay for cows, 383; horses, 311
June grass, see Bluegrass

Kafir, 170–1
for calves, 426; cows, 366; horses, 305; pigs, 637; sheep, 557; steers, 476
may contain poison, 204, 252
Kafir fodder, 203–4
for beef cows, 511; steers, 493, 517–8
Kafir silage, 204
for beef cows, 511; dairy cows, 388; sheep, 571; steers, 503, 517–9
Kafir soilage, 204
Kafir stover, 203–4
for beef cows, 511; steers, 493, 517–8
Kale, 249
Kaoliang, 170, 171
for pigs, 638
Kaoliang fodder and stover, 203–4
Kellner's starch values and feeding standard, 120–1
Kentucky bluegrass, see Bluegrass
Kidneys, elimination of waste thru, 36
Kindness, effect of, on digestion, 53, 405
Kohlrabi, 248
Kudzu vine, 241

Labor, see Work
Labor, distribution of in livestock farming, ix
Lactase, 25
Lactation, effects of advancing, 348
Lacteals, 34
Lambing, date of, 577
Lambs, see Sheep
compared with calves and pigs, 587
fattening, 590–5
fattening in the cornfield, 593
fattening in the fall, 593
fattening in the winter, 594–5
fattening western lambs, 590
feed and care of, 583, 586–97
gains by, 540
hot-house, 595–7
orphan, 586
rations for fattening, 592
returns from, compared with other farm animals, 90–2
rich and poor milk for, 79
spring, 597
weaning, 588
weight of, at birth, 584
winter, 595–7
Lamb's-quarter seed for pigs, 639
Larkspurs, poisoning from, 255

Leaves and twigs, 250
Legume hay, importance of, for beef cows, 508, 510; brood sows, 686–8; dairy cows, 375; ewes, 581; horses, 304, 313; pigs, 680; sheep, 550–1, 562–3; steers, 470–2, 487–8
Legumes for forage, 225–41
see Alfalfa, Clover, etc.
Legumin, 7
Leguminous seeds, 179–81, 182
see Peas, Beans, Soybeans, etc.
Leguminous roughage rich in lime, 66, 225
Lespedeza, 239
Lespedeza hay, 239
for cows, 381; horses, 315; steers, 492
Light, importance of, for farm animals, 75
Lime, see Calcium
Lime phosphate, see Calcium phosphate
Linseed cake, see Linseed meal
Linseed meal or cake, 177–9
for beef cows, 509–10; calves, 427, 431; dairy cows, 371; horses, 307; pigs, 655–8; sheep, 559; steers, 484
new and old process, 178
Linseed oil meal, see Linseed meal
Lipase, 24
Liver, 24
Live stock and profitable farming, vii–x
consume feed otherwise wasted, viii
employ labor thruout year, ix
promote intelligent and progressive agriculture, ix
utilize land unsuited for tillage, ix
Loco poisoning, 254
Lucerne, see Alfalfa
Lymph, 33
Lymphatics, 33

Maintenance of farm animals, 56–75
Maintenance ration, see Ration, maintenance
Maintenance requirements, 56–76
factors influencing, 59–61
of dairy cows, 357–8; horses, 287; pigs, 606
Maize, see Corn
Malt, 164
Maltase, 25
Malt sugar, 4–5
Malt sprouts, 165
for cows, 369
Mammoth clover, see Clover, mammoth
Mangels, 244
dangerous to rams or wethers, 244, 567
for cows, 390–2; pigs, 676; sheep, 566–8; steers, 504–6
Manure, 273–82
amount voided by farm animals, 280–1
barnyard, benefits the soil, 273
care of, to prevent loss, 282
composition and value of, 279
fertilizing constituents recovered in, 274
influence of feed on, 275
losses in, 281
value of 1 ton from farm animals, 279
see Fertilizers
Manurial value of feeds, 275–7
Manyplies, 19
Mare, brood, feed and care of, 319–21
gestation period of, 320
see Horse
Mare's milk, composition and yield of, 323
Margin in fattening live stock, 446
Marsh gas, or methan, 23, 29, 45, 47
Marsh hay, 216
for cows, 383; for sheep, 565
Mastication, 20
energy lost in, 46
Meadow fescue, 213
Meat, marbling of, 84
Meat meal and meat scrap, see Tankage
Melons, 249
Metabolism, 32–6

Metabolizable energy, 46
Middlings, see Wheat middlings, Oat middlings, etc.
Milk cows, see Cows
Milk, cow's, 183, 345–56
ash in, 78–9
bitter, 355
color of, affected by feed, 356
colostrum, 79
composition of, 78–9, 183, 345
factors influencing, 346–56
influenced by age of cow, 347; condition at calving, 349; exercise, 354; feed, 349–52; individuality, 346; period between milkings, 347; stage of lactation, 348; turning to pasture, 353; work, 354
cost of producing, 410–5
effects of rich, on infants, 79; young animals, 79
fat globules in, 346
fat, source of, in, 107
feeding value of, 183
first and last drawn, composition of, 347
flavor, affected by feed, 355; rape pasture, 248; rye pasture, 212
for calves, 425, 429, 435; foals, 324; lambs, 586; pigs, 704
odors in, due to feed, 355
of different breeds, 345
pasteurizing to avoid disease, 184, 430
production of, 106–10
nutrients required for, 108–10
secretion of, 106
the natural food for young animals, 78
value of, as a human food, 337
yield, factors influencing, 346–56
of great dairy cows, 344, 421–2
Milk, ewe's, 78, 585; mare's, 323; sow's, 78, 698
Milking cows 3 times daily, 355
Milking, Hegelund method, 405
Milking machines, 354
Millet, foxtail, 172, 211; German, 211; hog, or broom-corn, 172; Hungarian, 211; Japanese, 211; pearl, 211
Millet hay, 211
dangerous to horses, 311
for horses, 311; lambs, 565
Millet seed, 172
for pigs, 639; sheep, 559; steers, 477
Millet silage for cows, 390; steers, 504
Milo, 170, 171
for calves, 426; cows, 366; horses, 305; pigs, 638; sheep, 558; steers, 476–7
Milo fodder and stover, 203–4
Mineral matter, 3, 8, 17, 64–9
controls life processes, 65
digestion of, 29
effects of lack of, 65–7; 68, 82, 93–4
importance of, in food, 65–69
in animal body, 16–7
in feeding stuffs, 8, 10, 66–7, Appendix Table VII
in plants, 3, 8, 10
required by various animals, see Horses, Swine, etc.
required for growth, 82–3; maintenance, 64–9; milk production, 109, 361
storage during growth, 76, 77, 82–3
see Calcium and Phosphorus
Mineral mixtures, see Mineral supplements
Mineral supplements for stock, 67, 83, 109, 194, 361, 602–6
Mixed feeds, 191
for pigs, 641; steers, 480
Modified Wolff-Lehmann feeding standards, see Morrison standards
Molasses, beet, 188
for cows, 366; horses, 306; pigs, 640; sheep, 558; steers, 480
Molasses, cane, 188
Molasses, cane, *continued*
for calves, 427; cows, 366; horses, 305; pigs, 640; sheep, 558; steers, 479
Molasses-beet pulp, see Beet pulp, Molasses
Molasses feeds, 189
for horses, 306; sheep, 559; steers, 480
Molassine meal, 189
Morrison feeding standards, 134–9; 140–7
Mules, 283, 318, 332
Muscles, cause of contraction, 102
increase thru exercise, 76
see Protein, also Muscular energy
Muscular contraction, 58, 102
Muscular energy, production of, 102

Natal grass, 215
Net energy, see Energy, net
Net nutrients, see Nutrients, net
Nitrogen, in feeds, as a fertilizer, 273–4
Nitrogen in fresh manure, 279
Nitrogen voided by farm animals, 274, 279–81
Nitrogen-free extract in feeds, how determined, 11
Nitrogenous compounds in plants, 2, 7–8
Nitrogenous feeds, 42
Nitrogenous waste in urine, 45, 47
Nutrients, 18
digestible, 18, 40–1
final uses of, 35
required by brood sows, 685; dairy calves, 423; dairy cows, 108–10, 357–362; horses, 103, 287, 290–2; pigs, 601–6; sheep, 110, 592; steers, 521
total digestible, 40
Nutritive ratio, 41
how calculated and expressed, 41
narrow and wide, 41
see Protein

Oat and pea hay, 237, 564
Oat and pea silage, 237
for cows, 389; sheep, 572; steers, 504
Oat dust, 163
Oat feed, 163
for cows, 383
Oat hay, 212
for horses, 310
Oat hulls, 162
Oat middlings, 163
Oats, 161
bleached and clipped, 162
by-products of, 162–3
for calves, 426, 431; cows, 365; ewes, 580; foals, 323, 325–7; horses, 301–2; pigs, 635; sheep, 556; sows, 689; steers, 475
weight of, 161
Oat sheaves, for steers, 494
Oat shorts, 163
Oat straw, 218
for horses, 312; sheep, 565; steers, 494
see Straw
Oat substitutes for horses, 302
Odors in milk, due to feed, 355
Oil cake, see Linseed meal or cake
Oils, see Fats
Olein, 6
Omasum, 19
Order and quiet, importance of, for cows, 404; sheep, 591; steers, 526
Orchard grass, 210
Osage oranges for cows, 392
Ox, see Steer
Oxidation of nutrients in body, 57, 102
Oxygen intake increased during work, 102
Oxygen in plants, 3

Palatability, 30–1
Palmitin, 6
Palm kernel meal, 373
Palmo midds, 191
Pancreas, 24
Pancreatic juice, 24

Para grass, 215
Parsnips, 245
for horses, 316
Pasteurizing dairy by-products to avoid disease, 184, 430, 642
Pasturage vs. soilage for cows, 263, 392
Pasture, abuse of, 216
fattening cattle on, 527–32
for beef cattle, 527–32; dairy cows, 393, 406; horses, 315; pigs, 664–76; sheep, 573–6
midsummer shortage of, 216
Paunch, 19
see Stomach
Pea-cannery refuse, see Pea-vine silage and Pea-vine waste
Pea meal, see Pea, field
Peanut, 180, 240
Peanut feed, 181
for cows, 374; pigs, 661; steers, 487
Peanut hulls, 181
Peanut meal or cake, 180
for cows, 374; horses, 309; pigs, 661; sheep, 561; steers, 486
Peanut oil feed, see Peanut feed
Peanut oil meal, see Peanut meal
Peanuts for pigs, 661, 679
Peanut vine hay, 240
Pea, field, 181, 237
for horses, 309; sheep, 560, 564; pigs, 658, 672
hay, 237
for cows, 381; horses, 315; sheep, 564
Pea pasture for pigs, 672
Pea straw, 219
for sheep, 564
Pea, Tangier, 240
Pea-vine silage, 237
fattening sheep on, 572
for cows, 388
Pea-vine waste, from canneries, 237
Pentosans, 4, 6
a source of body fat, 88
digestion of, 23, 27
in dried brewers' grains, 165; flax seed, 177
Pentose, 4, 6
Pepsin, 21-2
Peptones, 22, 27
Phosphate, calcium, for farm animals, 68, 82
Phosphate, ground rock, for calves, 428; cows, 362; farm animals, 68, 82; foals, 325; pigs, 82, 602-5
Phosphoric acid in feeds as a fertilizer, 273-4
Phosphoric acid in fresh manure, 279
Phosphoric acid voided by farm animals, 274, 280-1
Phosphorus, 3, 8, 17
effect of low supply, 66, 82
feeds low in, and rich in, 67, 83, Appendix Table VII
in bran, 160
inorganic, for animals, 67
required for maintenance, 64-8; growth, 82-3
stored by calf, 77
Pigeon-grass seed for pigs, 639
Pigs, 599-708
(For value of various feeds for pigs see different feeds; i.e., Corn, Clover hay, etc.)
age, influence of, on gains, 599-601
air breathed by, 69
bacon production, 621-2
barrows vs. sows, 620
birth weight of, 694
body of, composition, 16
body temperature of, 57
bone for, ground, 68, 82, 603-5
breed tests, 619
composition of increase during fattening, 84
Pigs, *continued*
concentrates for, 623-664
cooking feed for, 271, 609-10
correctives of mineral nature for, 602-6
digestibility of food by, 54
dressed carcass, per cent yielded by, 620
economy of meat production by, 90-2 599-601
exercise for, 618, 692
fall pigs, raising, 702
fattening, 700
fattening period, effect of lengthening, 599-601
feed eaten daily, 599-601
feed for 100 lbs. of gain, 599-601
feeds for, 623-83
feeding corn exclusively, 92-6, 623-5
following steers, 523
forage crops for, 664-76
free choice method of self-feeding, 615
gains from birth to maturity, 599–601, 700
grain, amount to feed on pasture, 610-5
grinding grain for, 270, 607-9
ground rock phosphate for, 82, 603-5
hairless, 68, 605-7
hog cholera vaccination, 705
hogging down corn, 628-30
hogging down ripe grain, 675
influence of feed on body, 92-6
influence of length of fattening period on gains, 599-601
intestines, length of, 620
lice, 704
limited vs. full feeding, 610-3
maintenance requirements of, 606
milk only for, 74
milk, rich and poor, for, 79
mineral matter requirements of, 66-9, 82, 602-6
mineral supplements for, 603-6, 616
number in litter, 694
nutrient requirements of, 601-7
orphans, 704
phosphorus-poor rations, effect of, 82
pork from, see Pork
preparation of feed for, 269-72, 607-10
protein requirements of, 602
razorback, 620
returns from, compared with other farm animals, 90-2
rickets, 73, 606
roughage for, 664–83
salt required by, 603, 692
sanitation and disease prevention, 704
self-feeding, 613-6
shelter for, 617, 692
soaking feed for, 272, 610
soft pork from, see Pork, soft
sows, see Sows
stock foods for, 616
strength of bones affected by feed, 82, 93-6, 602
stubble fields, gleaning, 676
succulent feeds for, 664-80
suckling pigs, 697
summer vs. winter feeding, 616
tuberculosis, from tuberculous steers or infected milk, 184, 642
types of, 618
vitamine requirements of, 606-7
water required by, 616, 692
weight at birth, 694
wetting feed for, 610
winter care and feed of, 703
worms in pigs, 704-5
see Swine, and Sows
Plants and animals compared, 17
Plants, carbon dioxid, food for, 2
composition, at different stages of maturity, 12-14, 50-2, 206, 208, 232

Plants, *continued*
composition, factors influencing, 50-2
elements present in, 1-4
food of, 1-4
how they grow, 1-9
poisonous, 252-5
support animal life, 9
use of mineral matter in, 3
water required by, 1
Plant substances, how grouped, 9-12
Poisonous plants, 252-5
Pork cracklings, 186
Pork, effect of barley on, 632; beans on, 659; buckwheat on, 639; corn on, 621; garbage on, 641; peas on, 621; peanuts on, 679; peanut meal on, 661; rice bran on, 640; skim milk on, 621; soybeans on, 621; squashes on, 678
Pork, soft, 621, 679
Potash, as a fertilizer in feeds, 273-4, Appendix Table III
in fresh manure, 279
voided by farm animals, 274, 280-1
Potassium chlorid, feeding in place of salt, 68
Potassium in blood, 64
Potassium iodide, cure for goitre, 68
Potatoes, 245
dried, 246
for cows, 392; horses, 316; pigs, 677
Potato silage for cows, 390
Potato, sweet, see Sweet potato
Poultry, returns of, compared with other farm animals, 90-2
Prairie hay, for cows, 383; horses, 311; sheep, 565; steers, 470, 517
Pregnant animals, food requirements of, 83
Preparation of feeds, 269-72
Prickly comfrey, 250
Prickly pear, 251-2
for silage, 260
see Cacti
Proprietary feeds, 191-3
Protein, 7-8, 15
absorption of, 35
amount in rations, adapting to local conditions, 147
a cell stimulant, 63
building of body protein, 28
complete and incomplete, 63, 80-2, 623-6
crude, 7
how determined in feeds, 11
digestion of, 27
fat formed from, 88
in animal body, 15
liberal supply essential to normal growth, 76, 80
muscular energy from, 101-2
quality of, important in stock feeding, 63, 73, 80-2, 623-6
replaced by amids, 63
required for growth, 80
maintenance, 61-4
requirements for various classes of animals, see respective animals
stored in body during growth, 76-7
waste of, from body, 36, 61
Protein metabolism, 35-6, 61-4, 80-2
Proteoses, 22, 27
Protoplasm, plant, 4, 7
Prussic acid, plants carrying, 252
Ptyalin, 21
Pumpkins, 249
for cows, 249; pigs, 678
Pumpkin seeds, 249
Purslane, 250

Quarters for farm animals, see Shelter
Quiet, importance of, for farm animals, 75

Ram, feed and care of, 578
see Sheep

Rape, dwarf, Essex, 248
for cattle, 248; pigs, 664-9, 673; sheep, 574-6
Rapeseed cake, 309, 373
Rations, 18
balanced, 18
limitations of, 117
bulkiness of, importance of, 115
calculating, for dairy cows, 132, 140-7, 395-401; fattening steers, 137-9; steers at rest, 118-20, 126-7
complete and incomplete, 73, 117
digestibility of, factors influencing, 50-5
economical, for farm animals, 140-50
for various farm animals, see Feeds, also Horse, Cow, etc.
general requirements of, 114-8
hints on calculating, 118
maintenance, 18, 56-75
economical, 49, 59
factors affecting requirements for, 59-61
for various farm animals, Appendix Tables IV and V, see also Horse, Pig, etc.
scanty, influence on growth, 97-100
standard, see Feeding standards
Red clover, see Clover, red
Red dog flour, 160
for pigs, 655
Red top grass, 210
Regularity, importance of, for farm animals, 75, 299, 405, 526, 591

Rennet, 22
Rennin, 22
Rescue grass, 215
Respiration apparatus, 43
Respiration calorimeter, 44
Respiration studies with ox, 43-4
Reticulum, 19
Rice, 168
damaged, value, 169
red, feeding value, 169
returns from barrel of, 168
rough, for horses, 306; pigs, 640
Rice bran, 168
Rice by-products and rough rice for steers, 477
Rice by-products for pigs, 640
Rice hulls, 168
Rice meal for calves, 426
Rice polish, 169
Rice straw, 219
Rickets, 73, 75, 606
Roads, draft required on various, 285
Rock phosphate, see Phosphate, rock
Roots and silage, relative yield and cost of, 243-4
Roots and tubers, 242-7
costly, 243, 391
for cows, 390-2; horses, 316; pigs, 676, 690; sheep, 566-8; steers, 504-6
value of dry matter in, 242
versus concentrates for dairy cows, 242, 391
versus corn silage, 243
for cows, 390-2; sheep, 567; steers, 505
yield of, and dry matter in, 243-4
Roughages, 12
adapting proportion of roughages and concentrates to local conditions, 148
compared with concentrates, 48
digestibility of, affected by wide nutritive ratio, 53
effect of storage on digestibility of, 52
excess injurious to horses, 310
for various farm animals, see Feeds
losses of energy in digestion of, 46-50
necessity of, for various farm animals, 74, 432
steaming for cattle, 271
Rumen, 19
Ruminants, 19

Ruminants, *continued*
digestibility of food by, 54
digestion of food by, 23
Russian thistle, 251
Rutabagas, 245
for cows, 391; horses, 316; lambs, 566–7; steers, 505
Rye, 166
effect on dairy products, 166, 365
for cows, 365; horses, 305; pigs, 636
Rye bran, 166
Rye feed, 166
Rye grass, English, 213; Italian, 213
Rye hay, 212
Rye middlings, 166
Rye pasture, 212
for cows, 212; pigs, 675; sheep, 574
Rye silage, 212
for cows, 390
Rye straw, 218

Sagebrush, 250
Saliva, action on food, 21
secretion of, 20
Salt, common, 68
effect of, on digestibility, 54
for beef cows, 508; dairy cows, 68, 403; calves, 428; horses, 297; pigs, 603; sheep, 546; sows, 692; steers, 523
in blood, 64
need of, by farm animals, 68
withholding, from cows, 68
Saltbush, 250
Salvage grain, 191
Sawdust, hydrolized, 250
for cows, 384
Scandinavian feed unit system, 131
Scarlet clover, see Crimson clover
Scours in calves, 438
Screenings, see Wheat screenings
Self-feeding calves, 428; pigs, 613–6; sheep, 544; steers, 459
Separator skim milk, see Skim milk
Serradella, 240
Serum albumin and globulin, 35
Sesame oil cake, 309
Shallu, 170, 172
Shallu fodder and stover, 203
Sheep, 537–98
(For the value of different feeds for sheep, see the various feeds; i.e., Corn, Clover hay, etc.)
age, influence of, on gains, 540
air required by, 69
body temperature of, 57
breeding studies of, 584
breed tests of, 539
building up the farm flock, 540
care and management of, 577–598
chopping hay for, 544
composition of body, 16
concentrates for, 550–62
cost of gains by, 592
cost of keeping, 582
cross breeding, 539
daily gain of, 540
danger from feeding mangels, 245, 566
dipping, 591
dressed carcass, per cent yielded by, 548
exercise for, 543
fattening, 590–5
different ages, 540
in Great Britain, 567
in the corn belt, 595
in the corn field, 593
in the East, 595
in the fall, 593
in the West, 594–5
length of feeding period, 592
proportion of concentrates for, 592
rations for, 550–76, 592
feeding, hints on, 590–5
Sheep, *continued*
feed racks for, 545
feeds for, 550–76
flock, proper size of, 538
general problems in sheep husbandry, 537–49
gestation period, 577
grinding grain for, 543; hay for, 544
increase during fattening, 84
mineral matter for, 546
mutton and Merino, compared, 538
place on the farm, 537
regularity and quiet for, 591
returns compared with other farm animals, 90–2
roughages for, 562–76
salt required by, 546
self-feeding, 544
shearing before fattening, 549
shelter for, 541–3
shrinkage in shipping, 548
size of the flock, 538
slaughter tests, 547
stomach worms, 589
succulent feeds for, 566–76
turning to pasture, 588
types of, 538
water required by, 545
weight of fattened, 546–8
winter quarters for, 541–3
wool production, see Wool, see Ewes and Lambs
Shelter, for cows, 403; farm animals, 60–1; horses, 298; pigs, 617; sheep, 542, 579; steers, 466–7; sows, 692
Shipstuff, see Wheat mixed feed
Shock corn, see Corn fodder
Shorts, see Wheat middlings
Shotes, see Pigs
Shredding corn forage, 202
see Corn forage
Shrinkage in shipping sheep, 548; steers, 498
Silage, 256–66
advantages of, 197–9, 259
alfalfa, 230
amounts to feed various animals, 262
apple pomace, 260
as a feeding stuff, 261
beet leaves and tops for, 260
clover, 234, 260
Silage, corn, 197–200
for dairy calves, 432; beef cows, 509–10; dairy cows, 384–7; ewes, 582; horses, 316; pigs, 680; sheep, 567–71; sows, 690; steers, 495–502; 517–9
removing ears from corn before ensiling, 200–1, 387–8, 501–2
versus corn fodder, 199, 385
versus hay for cows, 386
versus roots, 243
for cows, 390–2; lambs, 567; steers, 505
versus shock corn for steers, 501
corn stover, 200–1
see Corn stover silage
Silage, cost of producing, 260
cowpea, 238, 260
crops suitable for, 259
cured corn forage for, 200
digestibility of, 53
effects on milk, 385
frosted corn for, 200
importance of, on stock farm, 261
losses in silo, 198
pea-vine, 237
preservation, manner of, 256
prickly pear, 260
sorghums for, 204
space occupied by, 259, 264
spoiled, dangerous, 254
steaming, 257
summer, 262
for cows, 262, 385

Silage, *continued*
thistles for, 260
versus soilage for cows, 266–8, 392–3
weight of, 264
Silage and roots, relative cost of, 243–4
Silo, 256–66
capacity of, 264
danger from carbon dioxid in filling, 264
economy of various sizes, 258
filling, 263
proper size of, 265
requisites of a good, 257
types of, 258
Skim milk, 183
for colts, 324; cows, 375; calves, 425–8, 430–1; pigs, 642–6
money value, for pigs, 644
pasteurising to avoid disease, 184, 430, 642
proper proportion for pig feeding, 645
substitutes for, in calf rearing, 434–7
Skin, losses of heat from, 58–9
Slaughter-house waste, 185–6
Smut, corn, 254
Soaked feed, 272
for cows, 404; horses, 296; pigs, 272, 610
Soft pork, see Pork, soft
Soilage, 266–9
advantages of partial, 266
alfalfa for, 229
cereals for, 212
clover for, 234
corn for, 202
crops for, 268
disadvantages of, 262, 266, 393
for cows, 392; pigs, 676; sheep, 575
sorghums for, 204
versus pasturage, 267
versus silage, 262, 267, 392
Soiling chart, 268–9
Sorgho, see Sorghum, sweet
Sorghum fodder or hay, 203–4
for horses, 311; sheep, 565; steers, 493
Sorghum hay, see Sorghum fodder
Sorghum pasture, 204
for pigs, 676
Sorghum, prussic acid in, 252
Sorghum silage, 204–5
for beef cows, 511; dairy cows, 388; sheep, 571; steers, 503, 517–8
Sorghum soilage, 204
Sorghum stover, 203–4
for steers, 493
Sorghums, grain, 169–72
see Kafir, Milo, Feterita, Kaoliang, Durra, Shallu
Sorghums, sweet, 169, 172
for cows, 366; pigs, 638
Sotol, 251
Sows, 684–98, 701–2
age to breed, 701
amount of concentrates to feed, 690
breeding studies, 694
care at farrowing, 695
composition of milk, 78, 698
exercise for, 692
farrowing time, 695
feed and care of, 684–99
feeding exclusively on skim milk, 74
gestation period, 694
grain alone unsatisfactory for, 685
legume hay for, 686–8
maintenance requirements, 606
milk, yield of, 698
nutrients required by, 685
number of litters a year, 702
shelter for, 692
spayed vs. unspayed, 621
succulent feeds for, 690
versus barrows, 620
wintering, 685–93
see Pigs
Soybean, 179, 238
for cows, 372; horses, 309; pigs, 659; sheep, 560; steers, 484, 485
Soybean and corn silage for cows, 389; steers, 504
Soybean hay, 238
for cows, 381; horses, 315; sheep, 563; steers, 492
Soybean oil meal or cake, 180
for cows, 372; pigs, 660; steers, 484
Soybean pasture for pigs, 672
Soybean silage for cows, 389
Soybean straw, 219
for sheep, 564
Spelt, see Emmer
Spread or margin in selling steers, 446
Spurrey, 250
Squashes, 249
for pigs, 678
Stables, see Shelter
Stallions, feed and care of, 328–9
Standard rations, see Feeding standards
Starch, 4–5
action of saliva on, 21
digestion of, 26
production of, from corn, 155
Starch values, Kellner's, 120
Starvation, effects of, 61, 97–100
Steam engine and animal compared, 44–46, 105–6
Steaming roughage for cattle, 271
Steaming silage, 257
Steapsin, 24
Stearin, 6
Steer feeding, counsel in feed lot, 521–36; importance of regularity and quiet in, 526; requires business judgment, 525
see Steers
Steers, 445–536
(For the value of the different feeds for steers, see the various feeds, i. e., Corn, Corn silage, etc.)
age, influence of, on gains, 77, 448–52
baby beef, 532–4
beef breeding, value of, 459–65
breeds compared, 465
calculating rations for, 118–20, 126–7, 137–9
compared with heifers for beef, 468
composition of, at different ages, 85–6
composition of increase during fattening, 84–5
concentrates, amount to feed, 455–9, 473, 501
concentrates for, 470–87
confinement vs. open shed for, 468
cost of fattening, 535–6
increases with age, 77, 448–52
increases with degree of finish, 452
counsel in the feed lot, 521–36
dressed carcass, per cent yielded by, 461
early maturity of beef breeds, 461
equipment for cattle feeding, 522
exercise for, 468
fat of, effects of cotton seed on, 176
fattened animal, indications of, 453
fattening, methods of, 527–36
on pasture, 527–32
on roughage, 491
on small allowance of concentrates, 455–9
feed consumed by various breeds, 463
feed consumed from birth to maturity, 448–50
feeds for, 470–506
feeding exclusively on concentrates, 74
feeding chiefly on roughage, 455–9
finish, degree of, effect on cost of gain, 452
frequency of feeding, 522
gains on grass, 528–9
gains from droppings, by hogs, 523
gains, influenced by age, 77, 448–52
getting on feed, 522
grain feeding on pasture, 529
grinding grain for, 270, 473–4
growth under adverse conditions, 97–100

Steers, *continued*
increase during fattening, 84–6
length of feeding period, 454
long vs. short feeding, 454
loose vs. tied, 468
margin required in fattening, 446
market grades compared, 463–5
mineral matter requirements of, 448
nutrient requirements of, 447
pasture for fattening, 527–32
paved feed lots for, 469
pigs following, 523
preparation of feed for, 269–72, 468, 473–4
preparing for shipment, 524
profitable type of, 465
proportion of valuable parts in carcass, 461
pure-bred or grade steers vs. scrubs, 459–65
quality, value of, 462
quarters for, 466
quiet, importance of, for, 526
rations fed by British feeders, 505–6
rations for fattening, 447–8
returns from, compared with dairy cow, 337–8; other farm animals, 90–2
roughages, for, 487–506
salt for, 523
self-feeding, 459
shelter for, 466
shipment, preparing for, 524
short vs. long feeding, 454
shrinkage in shipping, 524
silage for, 495–505
succulent feeds for, 495–506
summer vs. winter feeding, 528
tied vs. loose, 468
versus heifers for beef production, 468
vitamine requirements of, 448
water required by, 523
weight of fat, at Smithfield show, 465–6
weight of, variations in, 524
wide and narrow rations for, 96
wintering growing steers, 516–9
Stock foods and tonics, 193
for pigs, 616
Stock tonics, formulæ for, 194
Stomach, capacity of, 19
digestion in simple stomach, 21–2
digestion in compound stomach, 23
Stomachs of ruminants, 19, 23
Stomach worms in sheep, 589
Stooking corn, see Shocking corn
Stover, see Corn stover
Straw, 218–9
for beef cows, 510; dairy cows, 383; horses, 312; sheep, 565; steers, 494
from cereals, 218
from legumes and other plants, 218–9
Succulent feeds, value of, 74
for dairy calves, 432; cows, 384; horses, 315; pigs, 664–7; sheep, 566; steers, 495
Sucrase, 25
Sudan grass, 214
Sudan grass hay for horses, 311;
Sudan grass silage for cows, 390
Sugar, as a feed, 190, 306
Sugar beet pulp, see Beet pulp
Sugar beets, 245
for cows, 390–2; pigs, 676–7, 690; sheep, 566–8; steers, 504
Sugar cane, 215
Sugar factory by-products, 186–9
Suint in wool, 110,
Sunflower seed, 181
for pigs, 664
Sunflower seed cake, 181, 309, 373
Sunflower silage, 249
for cows, 389; sheep, 572; steers, 503
Sunflowers for forage, 249
Sun, the source of life, 9, 36
Swedes, see Rutabagas
Swedish clover, see Clover, alsike
Sweet clover, see Clover, sweet
Sweet potato, 246
Sweet potatoes for pigs, 678; steers, 505
Swine, see Pigs, Sows, and Boars
Systems of feeding, adapting to local conditions, 147–50

Tankage, 185
for horses, 309; pigs, 649–52; sheep, 561
Teeth, care of, in horses, 299
Teeth, wolf, in young pigs, 697
Temperature, body, of farm animals, 56
Temperature, effects of too high in stable, 61, 298
see Heat
Teosinte, 211
Testing associations, for dairy cows, 344
Therm, 45
Thistles, Russian, 251
silage from, 260
Timothy, 207–10
yield at different stages, 208
Timothy hay, 207–10
early and late cut, 208
for cows, 382; horses, 310; sheep, 565; steers, 493
Tonics, 193–4, 616
Tractor vs. the horse, 105, 295
Tree leaves and twigs, 250
Trotter, feed for the, 334
Trypsin, 24
Tuberculosis, pigs infected thru following steers, 643
Tuberculosis spread by feeding infected milk, 184, 430, 643
Tubers, see Roots and tubers
Tunis grass, 214
Turnips, 245
Twigs, see Tree twigs

Urea, 36
loss of energy in, 45–7
Urine, 36
fertilizing constituents voided in, 280
heat carried off by, 45
voided by farm animals, 278
waste of nitrogen in, 35–6, 45

Variety of feeds, importance of, 116
Veal production, 515–6
Vegetable ivory nut meal, 191
Velvet bean, 182, 239
for cows, 373; horses, 309; pigs, 663; sheep, 561; steers, 487
Velvet bean feed, 182
Velvet bean pasture for pigs, 673
Ventilation, see Air
Vetch, hairy, 239
Vetch, common, 239
Vetch hay for cows, 381
Villi, 34
Vinegar grains, 190
Vitamine mixtures, 194, 616
Vitamines, 71–4, 83, 110, 357, 423, 448, 606
anti-rachitic, 73
anti-scorbutic, 73
fat-soluble, 71
requirements of calves, 423; dairy cows, 357; steers, 448; pigs, 606
required for growth, 83; milk production, 110
water-soluble, 72

Waste of body, disposal of, 36
Water, effects of depriving animals of, 69
evaporation of, carries heat from body, 58, 70
for beef cows, 508; calves, 428; dairy cows, 402; farm animals, 69–71; horses, 297; lambs, 545; pigs, 616; sheep, 545; sows, 692; steers, 523
formed from breaking down of food, 71
frequency of drinking, 53, 70
influence on digestibility of feeds, 53

Water, *continued*
in feeds, how determined, 10
in plants, 1, 10
vapor of lungs, heat carried off by, 58
warming for cows, 70; farm animals, 70
Watering, time of, for horses, 297
Weaning colts, 324; dairy calves, 430; lambs, 588; pigs, 699
Weeds, silage from, 260
Weight, body, variations in, of horse, 292; of steer, 524
Wet beet pulp, see Beet pulp, wet
Wet brewers' grains, see Brewers' grains, wet
Wetting feed, for cows, 404; pigs, 607–10
Wethers, see Sheep and Lambs
Wheat, 157–8
by-products of, 158–61
effect of climate upon, 50
for cows, 365; horses, 305; pigs, 634; sheep, 555; steers, 475
shrunken and damaged, for stock, 158
Wheat bran, 159
cause of laxative effect, 159
for calves, 426, 431; colts, 325–7; cows, 367, 370, 408, 418–21; ewes, 580; horses, 307, 330; lambs, 587; pigs, 655; sheep, 561; sows, 686; stallions, 329; steers, 485
phosphorus in, 159
poor in lime, 159
Wheat bread, stale, feeding to animals, 159
Wheat grass, 213
Wheat hay, 212, 310
Wheat middlings, 160
for cows, 367; horses, 307; pigs, 653–5
Wheat mixed feed, 161
for cows, 367; pigs, 655
Wheat screenings, 161
for pigs, 639; sheep, 556
Wheat shorts, see Wheat middlings
Wheat straw, 218
Whey, 184
Whey, for calves, 434; cows, 367; pigs, 642, 648
Whole milk, see Milk, cow's
Wild grass, see Marsh hay, Prairie hay
Wild hogs, see Pigs, razorback
Winter lambs, 595–7
Wintering stock, see Steers, Sows, etc.
Wolff-Lehmann feeding standards, 113-4, 118–20, Appendix Table IV
Woll-Humphrey standard, 132
Wood ashes for pigs, 604–5
Wool, 110–1, 548–9
composition of, 110
influenced by feed, 111
production, 110–1, 548–9
Work, 101–6
carbon dioxid produced during, 102
effect on digestibility of feeds, 53, 285
energy requirements for, 102–4
factors influencing efficiency, 104
heat produced thru, 105
internal, produces heat, 46–50, 103
measurement of, 284
nutrients required by horses for, 288–92
nutritive ratio for, 290
of the horse, 284–92
performed by the horse, 284
protein waste during, 101–2
relative value of nutrients for producing, 102
severe, by the horse, 292
source of energy for, 101–3
types of, performed by the horse, 288
value of feeds for, 286
see Energy
Work animals, nutrient requirements of, 103-5. 288–92
see Horses
Work horse, see Horses
Worms in pigs, 704; sheep, 589

Yeast grains, 190
Yolk in wool, 110
Yucca, 251

Priscilla Guthrie's
Book Shop
William Penn Place
Pittsburgh